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GUIDE TO CAMOUFLAGE FOR DARCOM EQUIPMENT DEVELOPERS.

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This GUIDE TO CAMOUFLAGE FOR DARCOM EQUIPMENT DEVELOPERS was prepared by the Defense Division of the Brunswick Corporation, Deland, Fla. under Contract DAAG53-76-C-0216. The authorizations, responsibilities, procedures, and technical data presented in this Guide were derived from published regulations, classified and unclassified literature, direct contacts with Army installations and personnel, and consultation with experts in the field of camouflage. This Guide is, therefore, a composite of information gathered from many sources and verified by authorities in specific areas of camouflage.

This Guide is intended to provide a basic understanding of camouflage for those involved in the development of Army materiel. It should be disseminated to all levels in development agencies. It is especially important that the Guide be readily available to those involved in concept design through engineering design. The basic Guide is unclassified and published prepunched to enable the user to place in a binder to facilitate the inclusion of page changes. Required changes are scheduled to be published annually. Annex A to the Guide is classified SECRET and its distribution is more limited than the basic Guide in deference to the security control system. The annex should be scanned for content and used as necessary for reference while the basic Guide should always be at hand - on the developers desk.

U. S. Army Mobility Equipment Research and Development Command (MERADCOM) is the proponent for this publication. Comments, corrections, recommended changes and additions are solicited. All correspondence should be forwarded direct to:

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Fort Belvoir, Virginia 22060

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ABSTRACT

This Guide is a compilation of information relating to the subject of applying camouflage to DARCOM equipment. Camouflage critical and camouflage sensitive lists of items/systems are discussed and explained. The process of identifying item/system signature cues, and relating these to enemy remote sensing systems in order to achieve a threat assessment is reviewed. Capsule information on the many means and processes of remote sensors is presented to facilitate the threat assessment task. The role of military worth, measures of performance, and measures of effectiveness in determining cost effective countermeasure goals is addressed. Methods of achieving camouflage are defined and explained as is the definition of camouflage itself. The interfaces of camouflage with tactical cover and deception, electronic warfare and cryptography, are brought into focus. Different types of camouflage are explained with emphasis on the built-in type. Information about available camouflage techniques, materials, and materiel is cataloged. The task of testing camouflage is presented as the final process of obtaining effective camouflage for DARCOM equipment. Four types of information are presented throughout this Guide. They are: fundamental information about camouflage, procedural information for achieving camouflage, information by way of example, and references for further reading.

POLICY STATEMENT

The Mobility Equipment Research and Development Command (MERADCOM), Fort Belvoir, Virginia, has been designated as the Lead Laboratory for camouflage. The following references apply:

Regulation, AMCR 70-58, 24 Jan 1973, "Camouflage Research and Development for Army Materiel."

Letter, AMCRD-GP, AMC, 13 Feb 1974, "Designations of Items and Systems as Camouflage Critical (CC) or Camouflage Sensitive (CS)."

Letter, AMCRD-GP, AMC, 31 May 1974, "Incorporation of Camouflage into Designated AMC Materiel."

AMCR 70-58 requires that commanders of DARCOM major subordinate commands, project/product managers, and heads of separate activities be responsible for the design, development and incorporation of the necessary camouflage measures into those Camouflage Critical (CC) or Camouflage Sensitive (CS) item/systems for which they have overall responsibility. These camouflage measures shall satisfy all requirements of applicable requirements documents in reducing detection, recognition and identification perceptibility.

The system utilized within the Department of the Army (DA) to initiate and account for the development and improvement of materiel is based on the concept of exploiting new technologies and ideas within sound doctrine, and bringing together Army-wide input to establish essential & desirable levels of camouflage in the form of requirements documents such as Letter of Agreement (LOA), Letter Requirements (LR), and Required Operational Capability (ROC).

Camouflage is to be included as an integral function during the development of these requirements documents to ensure that materiel concepts will result in a militarily effective system. Although less important items may not receive the degree of formal analysis given the more important ones, the same logic is applied in making judgments and establishing the technical, doctrinal, and support requirements.

Once these requirements documents are approved and issued, they guide development to insure the best possible materiel within technology, time, and cost constraints. The progress of this development (including camouflage) is reviewed at prescribed points by representatives of concerned elements within the Department of Army. Decisions result from these reviews to accept, modify or cancel specific requirements or programs based upon progress or change in conditions on which the requirement is based.

The implementation of an effective camouflage program for DARCOM materiel, therefore, requires dedicated efforts and teamwork between all concerned elements of the Department of the Army; from the project manager through DARCOM, MERADCOM and the Training and Doctrine Command (TRADOC). Each of these elements play a vital role in achieving the long-term goals of reduced target perceptibility of DARCOM materiel.

This Guide facilitates the implementation of AMCR 70-58 and promotes the consideration of item/system perceptibility in the development of DARCOM materiel from its conceptual stages throughout its life cycle. The Guide provides procedures, current data, known techniques, and examples to guide the developer through all stages of a comprehensive camouflage program.

The Camouflage Laboratory at MERADCOM, Fort Belvoir, Virginia, is available to assist the user of this guide in threat assessment, camouflage and camouflage standards, military worth analysis, camouflage development, and testing. Although the equipment developer has overall responsibility for the implementation of camouflage into equipment, one mission of the Camouflage Laboratory is to assist the Developer in this effort. Such assistance can be provided at any level of effort ranging from minor consultation to the total development and application of a camouflage program for the Developer's item/system.

SECTION 1

INTRODUCTION

1.1 CAMOUFLAGE - NEW CHALLENGES AND DIRECTION

Camouflage is vital to survival on the modern battlefield. Correctly used, it can spell the difference between a successful campaign and defeat; to the individual it can mean the difference between life and death. Recent U.S. camouflage practices have been influenced by friendly mastery of the air and ability to dominate the battlefield with overwhelming combat power. This was the situation during the latter years of World War II and the Korean and Southeast Asia conflicts. Consequently only a very few of the U.S. military have experienced a hostile air attack.

There are numerous examples where camouflage has had a decisive effect on the outcome of a battle. It can be a powerful equalizer by increasing survivability and providing concealment. Concealment, in turn, may allow the field commander to successfully employ the doctrines of surprise and preservation of force.

The threat, as posed by a mid- or high-intensity conflict, is formidable. Brush piles and vacated campfires will no longer suffice for concealment and deception. Modern camouflage must deal with, and defeat, advanced state-of-the-art surveillance and target acquisition remote sensing systems. These sensors extend beyond the visual range to include all areas of the electromagnetic spectrum from microwaves to gamma rays and respond to sonic, seismic, chemical, and field effects. Available platforms for sensors have likewise multiplied in recent years to include helicopters, remotely piloted vehicles, and satellites in addition to fixed wing and ground based systems. The present and future threat is an enemy force that has an ability to search the battlefield for targets, and a significantly improved ability to deliver massive and accurate firepower upon selected targets.

There are at least four ways to counter the enemy's expanded capacity for gathering battlefield intelligence:

1. Prevent observation by keeping his sensors beyond their effective range.

2. Interfere with sensor operations or outputs by methods such as jamming or false signal insertion.

3. Conceal the target.

4. Falsify information about the target.

Camouflage is concerned with the third and fourth means, the concealment of targets and falsification of target information.

Because of continuing advances in sensing capabilities, it became increasingly evident in the early 1970's that the application of "camouflage" in the field by troops was no longer sufficient to meet the challenge of modern sensor threats. Therefore, on 11 January 1973, DARCOM (then AMC) chartered the Mobility Equipment Research and Development Command (MERADCOM, then MERDC) as the Lead Laboratory for camouflage technology and, on 24 January 1973, issued AMC Regulation 70-58 "Camouflage Research and Development for Army Materiel," which sets forth specific responsibilities, and policy.

DARCOM recognized that no single organization could meet the long-range camouflage objectives imposed by this regulation. As a result, a significant element of this regulation was the assignment of responsibility for the incorporation of camouflage into DARCOM materiel to all commanders of major subordinate commands, project/product managers, and heads of separate activities. This action placed the responsibility for the camouflage of equipment called for in applicable requirements documents with the developers of that equipment.

A second major element of the Regulation is the concept of "built-in" as opposed to separate field-applied camouflage materiel. This concept recognizes that reduced perceptibility of an item/system can be achieved at lower costs and with more success by incorporating camouflage into the item or system during its development, rather than by adding camouflage after the item is fully configured. This does not mean, however, that there is no need to localize camouflage for various world-wide terrains. Certain field operations are still required by the troops in achieving successful concealment in specific local backgrounds, such as careful site selection and the application of camouflage screens, local foliage, etc.

The opportunity to achieve the "built-in" camouflage objectives of AMCR 70-58 is directly related to the status of an equipment item in its life cycle.* Items in the early stages of concept formulation provide the best opportunities for incorporating built-in camouflage features. However, there are many things that can be done at later stages in the life cycle to reduce perceptibility.

1.2 PURPOSE AND SCOPE

1.2.1. Purpose

The purpose of this Guide is to:

- Assist major subordinate commanders, heads of separate activities, and project/product managers in understanding the DARCOM camouflage technology program, executing DARCOM policy in this field, and fulfilling the respective responsibilities which AMCR 70-58 has assigned to them.

* DA Pamphlet No. 11-25, Life Cycle System Management Model for Army Systems, May 1975

- Describe the types of surveillance/target acquisition threats likely to be encountered; define the type countermeasures available (camouflage techniques in particular); provide insight into the particular problem of evaluation associated with this field; indicate where more comprehensive data may be found in particular areas of technology; and show, by example, how this information may be utilized by equipment developers.

- Assist TRADOC and other Army agencies by providing insight into the DARCOM camouflage technology program, and aid in the formulation and evaluation of camouflage requirements for insertion into the respective requirements documents.

- Assist in achieving the goals of lowered perceptibility of U.S. Army equipment to better achieve survivability on the battlefield.

1.2.2 Scope

The Guide reviews the basis for the DARCOM camouflage program, describes the threat to be countered by the application of camouflage principles and techniques, outlines program procedures, and provides a series of camouflage techniques and camouflage testing and evaluation procedures.

Figure 1-2 shows the logical progression of steps to be taken in achieving successful camouflage of DARCOM materiel in development. Blocks in the diagram correspond to detailed coverage in the indicated sections of this Guide. Within each section, the information is presented sequentially with examples, where appropriate, that illustrate methodologies and rationable in the determination and application of camouflage technology. A more detailed discussion of these steps is presented in paragraph 1.4. When applicable, references are listed at the end of each section to assist the reader in finding additional pertinent information.

Specific camouflage-related subjects of interest which are beyond the scope of this Guide are:

- Tactical Cover and Deception
- Electronic Warfare
- Cryptography
- Aircraft (In flight).

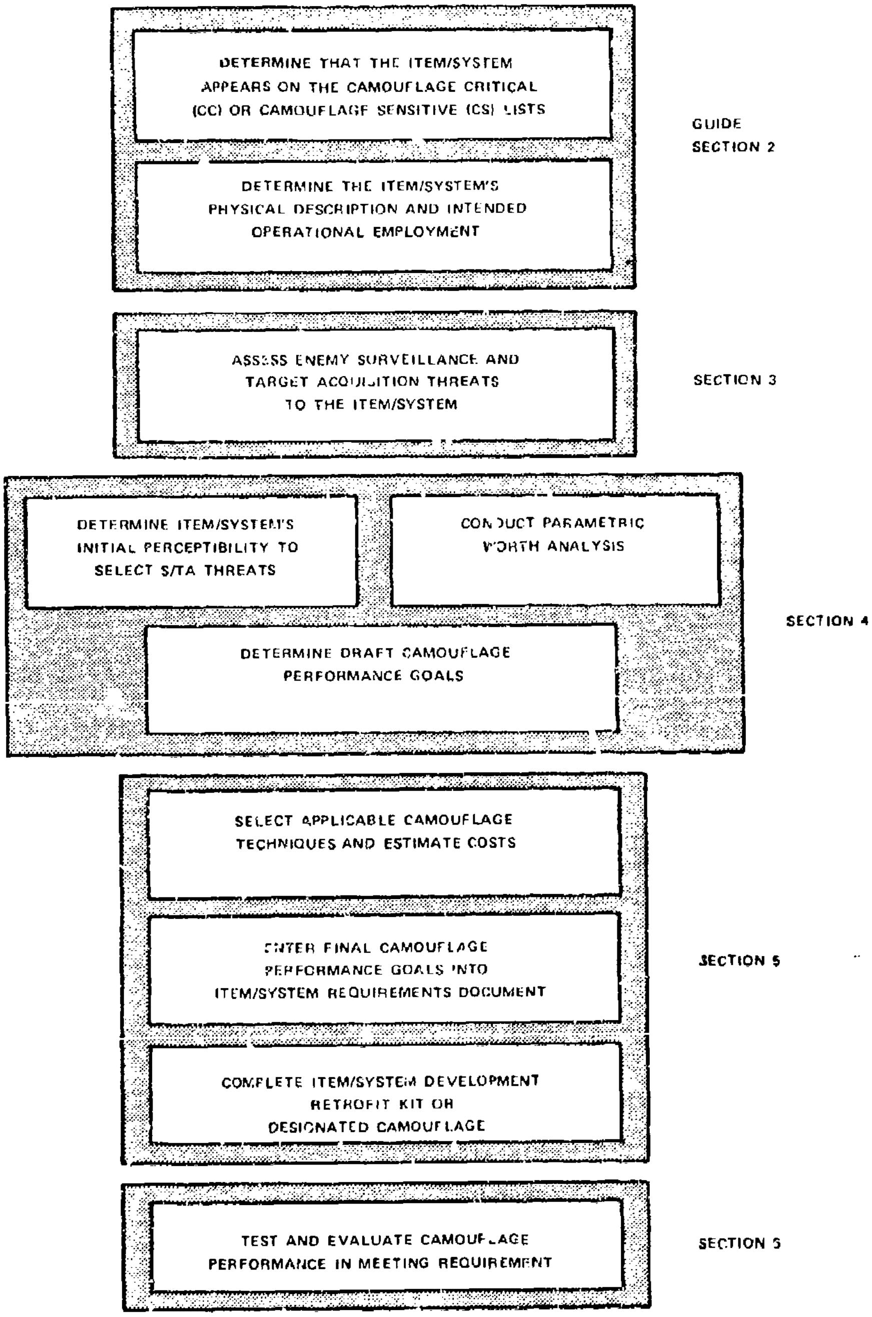


Figure 1-1 Process for Achieving Camouflage of DARCOM Materiel

- Tactical Cover and Deception

Tactical Cover and Deception for our purpose in this guide, refers to those integrated measures taken as part of battle plans and may, or may not utilize techniques, materials or equipment that are considered as camouflage. The terms *decoy, disguise* and *deceive*, when used with Tactical Cover and Deception, shield true capabilities and interests while providing evidence of false force capability or intent and is generally performed by combat teams of division size or larger.

When applied to Camouflage, the terms *decoy, disguise* and *deceive* are used in a protective sense to cause misidentification of targets, divide expected attack, or provide a lure to draw enemy fire on a unit or local level.

The use of decoys or disguises for camouflage purposes is under the jurisdiction of and at the discretion of the unit commander and is not related to battle plans beyond the unit level. For example, the deployment of decoys is a camouflage method not considered as tactical deception if accomplished for protective purposes by the unit employing the real weapon.

This Guide deals only with decoys and disguises developed for camouflage purposes which are protective in concept. The use of decoys or disguises to achieve tactical deception is not discussed.

- Electronic Warfare (EW)

EW is that division of the military use of electronics involving action taken to prevent or reduce an enemy's effective use of radiated electromagnetic energy, and actions taken to ensure one's own effective use of radiated electromagnetic energy. EW consists of electronic warfare support measure (ESM: listen to and locate enemy radiations), electronic countermeasure (ECM: jamming or deception to disrupt the enemy's use of electronics) and electronic counter-countermeasure (ECCM: protect friendly communication and non-communication systems).

Camouflage and ECCM share the similar characteristics of being passive, defensive and protective. The use of radar absorbing materials (RAM) and radar scattering screens could be classified under either discipline. In a parallel directive to AMCR 70-58, DARCOM policy* requires consideration of ECCM through the development and production of all equipment and systems dependent upon the electromagnetic spectrum for their operation.

*Letter, AMCRED-OE, "AMC Policy on Electronic Warfare," 2 January 1974

- Cryptography

  Although cryptography (EW in its ECCM role) and camouflage share a common purpose in denying meaningful and accurate intelligence to an enemy, their techniques are usually different.

- Aircraft (In actual or imminent combat)

  As in AMCR 70-58, this guide for camouflage addresses only the perceptibility of Army aircraft in a static condition where exposure might provide intelligence concerning military operations or lead to their destruction on the ground.

1.3 THE MEANING OF CAMOUFLAGE

"Camouflage" means different things to different people. This causes difficulty when people attempt to communicate about camouflage without first ascertaining that they really are discussing the same subject. It is appropriate, therefore, to discuss the concepts which are embodied in the definition of camouflage as it is used by the U.S. Army.

According to AMCR 70-58, camouflage is defined as the use of concealment to minimize the probability of detection and identification of troops, materiel, equipment and installations. Camouflage directly relates to increased survivability, mission accomplishment, and net tactical advantage by reducing the probability of detection, identification and location by hostile surveillance and target acquisition methods. Even in cases where Army units are detected or located, camouflage often results in increased probability of their survival. A net tactical advantage is gained by reducing the time available to hostile forces for tracking, aiming and firing at friendly forces. The effectiveness of delivered fire power is reduced by the added difficulty which camouflage causes enemy troops in their tasks of identifying vulnerable target features or selecting critical targets.

Physically, it is important to subdivide camouflage into the three types which are designated "built-in," "operational," and "field-applied." They are important relative to an item/system's life cycle status, the degree of freedom available in countermeasure selections, and the amount of effort involved in utilization.

Built-in camouflage is considered a design feature which is always present in the item/system and requires no thought or application by the field troops. "Add-on" camouflage is a subdivision of built-in camouflage which applies to a retro-fit situation, i.e., the camouflage would be built-in if the items/systems were new, but would be "add-on" if the items/systems

were already in the field. Examples of built-in camouflage include: exhaust cooling, shielding, or dissipation; structural arrangements to reduce highly reflective geometries; flash suppressors; etc. Many built-in features of these types can only be used successfully when an item/system is in its concept formulation, engineering development, or early prototype stages.

Operational camouflage is practiced by troops in field situations. It reflects the local tactical situation and the degree of camouflage emphasis applied by the field commander. Included are such matters as sound and light discipline, and the proper use of terrain and shadow in position and movement. Troop training and discipline will affect the success of operational camouflage.

Field applied camouflage is applied by troops in the field to themselves or to their equipment by using either locally available materials such as mud, brush, or grass, or materials issued from inventory, such as camouflage screens.

Flash suppression and thermal shielding incorporated into the design of a weapon are countermeasures, but are not subject to control by the user except in terms of employment. As viewed by an enemy, however, the camouflage employed whether applied or built-in is considered a countermeasure to his surveillance process.

The methods which are used to camouflage either physical/chemical or operational characteristics are not restricted to any given range or form of energy transmission, but will vary depending upon the item/system and the expected sensor threats to it. This often leads to more specific terminology such as radar camouflage, infrared camouflage, visual camouflage, etc.

1.4 HOW TO USE THIS GUIDE

This Guide contains camouflage development information and procedures which lead to answers to the following key questions:

- What items of Army equipment need camouflage?
- What types of sensor threats must the item/system be camouflaged against?
- How much and what camouflage is required?
- What technology is available to meet this requirement?
- How is camouflage tested and evaluated?

Armed with answers to these questions, the developer may then pursue the development and acquisition of camouflage in a manner similar to that for all the other features required in his item/system.

The first step in this procedure, as indicated in Figure 1-2 and discussed in Section 2, is that of determining whether or not an item/system is on the Camouflage Critical (CC) or Camouflage Sensitive (CS) lists. Items on these lists need the tactical benefits of camouflage to increase their survivability on the battlefield.

The second step in this procedure is to assure that an adequate description is available of the item/systems and a description of its intended operational employment. In the event that the item/system is still in the concept stage and not reduced to its military hardware configuration, this step may require several descriptions. Care should be taken to assure that these descriptions contain data on all aspects affecting detectability and identifiability.

The third step is to perform an assessment of the threat with the assistance of the Foreign Intelligence Office (FIO). This step is described in detail in Section 3 of this Guide. This threat assessment should identify and characterize the enemy surveillance and target acquisition (S/TA) threats that are of greatest concern to the item/system's survivability. The threat assessment consists of making comparisons of an enemy's remote sensing capabilities with the item/system's physical and operational characteristics in scenarios and world terrains of interest. This assessment leads to statements of specific detection and recognition capabilities expected to be encountered during the life of the item/system.

The next three steps are explained in Section 4 of this Guide. Two of the steps are conducted concurrently. First, based upon current threats and descriptions, a parametric worth analysis is conducted where several levels of camouflage performance capability are assumed (Step 4). Second, during this same time the initial (current) perceptibility is determined for the sensing threat (Step 5). Third, the differential between that level of camouflage performance capability found to produce military worth of significance and the current perceptibility of the item/system forms the basis for drafting camouflage performance goals (Step 6).

The next three steps (Steps 7, 8, and 9) are covered by Section 5. Step 7 reviews a number of the available techniques and means to achieve the level of camouflage performance capabilities indicated as necessary in Step 6. Step 8 estimates their development and life support costs if incorporated into the item/systems and Step 9 derives final camouflage performance goals. These goals form the basis for a statement(s) of camouflage requirements in the item/system's requirement document. This document is necessary to drive the development and acquisition of camouflage materiel and design for the item/system. Section 5 provides a summary of existing camouflage technology, and contains descriptions of off-the-shelf materials and materiel as well as discussions of the various techniques and methods which explain the effectiveness of camouflage.

The tenth and final step, which is covered in Section 6, performs tests to determine the item/system's camouflage performance in meeting the requirement goals. This testing leads to acceptance and type classification of the item/system. Section 6 describes test and evaluation methodology pertinent to determining and evaluating the effectiveness of camouflage.

1.5 REFERENCES

1. FM 50-20, Department of the Army Field Manual, Headquarters, Department of the Army, Camouflage, May 1968

2. MASSTER Test Report No. FM 155, Headquarters, Modern Army Selected Systems Test, Evaluation and Review, Camouflage Evaluation Report (Phase I), 21 January 1974

3. United States Army Training and Doctrine Command, TRADOC Bulletin 6, Weapons, Tactics, Training, Countersurveillance and Camouflage, October 1975 Unclassified

4. Department of the Army, Headquarters, U.S. Army Materiel Command, Washington, D.C., AMC Regulation No. 70-58, Research and Development Camouflage Research and Development for Army Materiel, 24 January 1973

5. DA Pamphlet No. 11-25, Life Cycle System Management Model for Army Systems, May 1975

6. Letter, AMCRED-OE, AMC, 2 January 1974, "AMC Policy on Electronic Warfare"

7. Letter, AMCDL, AMC, 11 January 1973, "Charter of US Army Mobility Equipment Research and Development Center as the AMC Lead Laboratory for Camouflage Technology."

SECTION 2

ITEM/SYSTEM SELECTION

2.1 CAMOUFLAGE CRITICAL/SENSITIVE LISTS

AMC Regulation 70-58, issued 24 January 1973, states that selected items and systems will be designated as either "Camouflage Critical" (CC) or "Camouflage Sensitive" (CS).

Accordingly, on 13 February 1974, Headquarters AMC issued a listing of materiel items and systems designated as camouflage critical and a similar listing of materiel items and systems designated as camouflage sensitive. These lists were revised and re-issued by Headquarters AMC, AMCRD-SE, 11 December 1975. Distribution was HQDA, HQ TRADOC, CACDA, and AMC Distribution A and B. The revised listings are titled "Categories of Materiel Items and Systems Designated Camouflage Critical (CC)" and "Categories of Materiel Items and Systems Designated Camouflage Sensitive (CS)". These listings include the specific notation that the examples given are not all inclusive. These listings are given in full in Section 2.4.

Specific items/systems appearing on the lists are the product of MERADCOM recommendations, TRADOC review, and DARCOM approval. (See Figure 2-1.) The items/systems selected and their relative priorities are established on the basis of combined estimates of:

- Threat posed to an enemy
- Replacement cost
- Operating proximity to zone of combat or forward edge of the battle area (FEBA)
- Enemy targeting priorities
- Contribution of the item/system to force effectiveness
- Enemy capability to destroy or neutralize the item/system's military effectiveness once located.
- Effect on other materiel and actions
- The current phase of the item/system's life cycle

These CC and CS lists are periodically revised and re-issued, with distribution to all concerned levels within DA, DARCOM, and TRADOC. DARCOM is responsible for reviewing the status of items/systems on the revised lists. TRADOC is invited to participate in these periodic reviews.

The CC list contains items/systems which are expensive, have operational capability critical to friendly forces, and pose a serious threat to the enemy. Such items/systems as nuclear delivery means and air defense weapon systems are typical of those included on the CC list. CC items/systems tend to be large, relatively few in number, and distinctive in appearance and/or activity.

The CS listing contains items/systems which are a combat threat to an enemy and whose operational capability is necessary for friendly force combat operations. Such items/systems are those that equip or support the fighting forces in the field and whose survivability will benefit from reduced perceptibility achieved through camouflage techniques. Trucks are included on the CS list, as well as crew served weapons, repair shops, and other materiel which would reveal the presence or identity of other items, systems or positions. The survivability of any item/system listed is considered sensitive to its degree of perceptibility.

The CC and CS listings are a compilation of battlefield items/systems that require camouflage.* Items/systems appearing on the lists are arranged in order of their priority with respect to the need for camouflage, whereas items/systems not appearing on the CC or CS lists are of no concern from a camouflage standpoint to the equipment developer. For example, items such as furniture, hand tools, and engine parts do not appear on the lists and do not require camouflage.

"Camouflage Critical" and "Camouflage Sensitive" designations are used by personnel in HQ DARCOM to establish schedule and funding priorities. The placement of items/systems on the camouflage critical list is a method of highlighting their importance to management and command personnel concerned with camouflage and is a notification to the developers of their responsibilities under AMCR 70-58. The item/system's development planning must be revised to place emphasis on camouflage in addition to all other item/system requirements.

CC and CS designations provide no significant distinctions to the item/system developer. Both designations require perceptibility determinations and camouflage, and nothing is to be implied about the degree of camouflage required for an item/system on the CC list versus an item/system on the CS list.

2.2 CC/CS REVIEW PROCEDURE

Commanders of DARCOM major subordinate commands, project/product managers and heads of separate activities are required to review the CC/CS lists to determine if their item/system is within a category listed therein. As shown in Figure 2-1, there are three separate paths that this review can take:

*Letter, AMCRD-SE, AMC, 11 December 1975, "Revised Camouflage Critical (CC) and Camouflage Sensitive (CS) Listings."

2.3 EXAMPLE PROBLEM

An example illustrating the material discussed in this section is presented in Appendix A of this guide.

2.4 CC/CS LISTINGS

The following listings of "Categories of Materiel Items and Systems Designated Camouflage Critical (CC)" and "Categories of Materiel Items and Systems Designated Camouflage Sensitive (CS)" were issued by Headquarters AMC, AMCRD-SE, 11 December 1975. These lists are not all inclusive.

DESIGNATION	ITEM/SYSTEM
CC 1	Nuclear Delivery Means
CC 2	Air Defense Systems
CC 3	Army/Corps/Division Tactical Headquarters
CC 4	Data Centers or Centrals Associated With Higher Headquarters
CC 5	Combat Vehicles and Armored Carriers
CC 6	Aircraft, Assault, Attack and Scout

EXAMPLES OF CAMOUFLAGE CRITICAL (CC) ITEMS AND SYSTEMS

CC 1 NUCLEAR DELIVERY MEANS

A. Missiles

Pershing, Lance.

B. Guns

Towed 155mm M114A1, 155mm XM198

Self Propelled 155mm M109A1, 8 inch M-110 and M110E2

C. Special Ammunition Supply Points

Nuclear Warheads

DESIGNATION	ITEM/SYSTEM
CC 2	AIR DEFENSE SYSTEMS
	A. Guided Missiles
	Chapparal, Hawk, Nike-Hercules, Redeye, PATRIOT, ROLAND, SAM-HIP, Stinger, ATAADS
	B. Guns
	Gun Air Defense Artillery 20mm, SP-M-163, Towed M-167 (Vulcan).
CC 3	ARMY/CORPS/DIV TACTICAL HEADQUARTERS
	Antennas - Modified Ground Plane and Dish Types.
	Heaters - Space - 45,000 BTU and 400,000 BTU
	Field Range, Gasoline Fired, 50 men multiples.
	Generator Sets, Gasoline or Diesel Engine 30 and 45 KW
	Tents - Gen Purpose - Med, Kitchen, and Frame Type Maintenance.
	Carrier Command Post M-577
CC 4	DATA CENTERS OR CENTRALS ASSOCIATED WITH HIGHER HEADQUARTERS
	Tactical Fire Direction System (TACFIRE), Tactical Operations System (TOS), Air Defense Command and Control System AN/TSQ-73 (Missile Minder).
	USASA Control and Analysis Centers (CAC)
	Communications Technical Control Centers AN/TSQ 83 and 84, Combat Service Support System (CS 3).
	Tactical Communications Switching Centers.
	Topographic Support System (Data Base Module) (including Antennas, Masts, and Dishes).

DESIGNATION	ITEM/SYSTEM
CC 5	COMBAT VEHICLES AND ARMORED CARRIERS

A. Tank Combat Full Tracked

Combat Engineer Vehicle, M-728.

105mm Gun M60 Series, 152mm Gun M60A2, XMI.

B. Carrier Personnel Full Tracked Armored

M-113 Series, Mech Inf Combat Veh (MICV).

C. Carrier Command and Reconnaissance

M-114 Series, Armored Recon Scout Veh (ARSV).

D. Other Carriers

For 81mm Mortar - M125AL, for 107mm Mortar M-106, M206A1.

For Flame Thrower - M-132, M132A1 for Chaparral GM, M730.

For TOW, M236.

E. Recovery Vehicle Full Tracked (Armored)

M806, M88, and M578.

F. Carrier Assault or Anti-Tank

Armored Recon Airborne Asslt Veh (ARAAV) M551, Vehicular Mtd TOW.

Vehicle Rapid Fire Weapons Systems (Bushmaster), Hyper Pressure/Hyper Velocity 105mm Gun, Vehicular Mtd 106mm Recoilless Rifle.

G. USASA SIGINT Collection and Electronic Warfare Facilities.

H. Division and Corps Area Communications Shelters.

DESIGNATION	ITEM/SYSTEM
CC 6	AIRCRAFT, ASSAULT, ATTACK AND SCOUT

A. Helicopter - Attack

AH-1 Series, Advanced Attack Helicopter (AAH).

B. Helicopter - Observation

OH-58 Series, OH-6, Aerial Scout.

C. Helicopter - Utility

UH-1 Series (HUEY), UTTAS.

D. Aircraft Observation

OV Series

E. Forward Area Refueling Equipment (FARE)

F. Forward Area Refueling and Rearming Point (FARRP).

NOTE: Each of the above designations include the essential support equipment which is necessary to provide a full operational capability or a total systems capability.

DESIGNATION	ITEM/SYSTEM
CS 1	Field Artillery and CB/CM Radar
CS 2	Radar - Ground Surveillance
CS 3	Brigade and Battalion HQ
CS 4	Anti-Tank Devices, Ground Mtd.
CS 5	Infantry Equipage and Fighting Positions
CS 6	Ammunition Supply Points
CS 7	Tactical Pol
CS 8	Aircraft - Support
CS 9	Tactical Bridges
CS 10	Trucks - Tactical and Logistical
CS 11	Combat Engineer Equipment
CS 12	Division Support Command
CS 13	Army Wide Items (High Signature)

EXAMPLES OF CAMOUFLAGE SENSITIVE (CS) ITEMS AND SYSTEMS

CS 1 — FIELD ARTILLERY (CONVENTIONAL ROUNDS) AND CB/CM RADARS

A. Howitzers and Guns

Towed	SP
105mm M101, M102, XM204	M107

B. Radars Counter Battery/Counter Mortar

AN/MPQ-4, AN/TPQ-36, AN/TPQ-37

CS 2 — RADAR - GROUND SURVEILLANCE

Radar Sets AN/TPS-25, AN/TPS-33, AN/TPS-58, AN/PPS-5, AN/PPS-15 and AN/TPS-58A.

CS 3 — BRIGADE AND BATTALION HQ*

Antennas - Ground Plane or Dish

*Note: Items common to CS3 and CC3/CC5 will use designation of CC3.

DESIGNATION	ITEM/SYSTEM
CS 3 (Contd.)	Heaters - Space - 150,000 BTU, 250,000 BTU and 400,000 BTU.
	Heaters - Immersion - Liquid - Fuel Fired.
	Intrenching Outfit - Infantry
	Stove - Gasoline Burner, Heavy Duty, 5000 BTU per Head.
	Field Range, Gasoline Fired, 50 Men Multiples
	Generator Sets, Gasoline Engines 1.5, 3, and 5 KW
	Radio Sets, AN/VRC-46, 47, 49, 64, and GRC-106 (Van).
	Trucks and Vehicles - Utility, 1/4T, Cargo, 3/4, 1-1/4, 2-1/2, 5T
	Ambulance - 1/4T, Wrecker 5T, Van 2-1/2T
	Fuel Service 2-1/2T, Water Tanker 400 gal, 2-1/2T, and Trailers - 1/4, 3/4 and 1-1/2T.
CS 4	ANTI-TANK DEVICES, GROUND MTD.
	Dragon, M202, TOW, LAW.
CS 5	INFANTRY EQUIPAGE AND FIGHTING POSITIONS
	A. Clothing and Equipment
	Coat, Shirt, Trousers (Man-Utility) in Tropical, Cold dry, Cold wet, Chem Protective, Camouflage Patterned, Over-white, Raincoat and Poncho Versions, Underclothing and Handkerchiefs.
	Boots, Combat Black, and Insulated Cold-wet-Black.
	Armor, Body Frag Prot, Nylon and Titanium/Nylon, Helmet Steel and Helmet Lightweight.
	Equipment, Load Carrying, Rucksack, Pack & Ammunition Vest and Frame LINCLOE.

DESIGNATION	ITEM/SYSTEM
CS 5 (Contd.)	Gloves, Wet or Cold.
	Covers - Intrenching Tool, Canteen, Ammo Pouch, First Aid Kit.
	B. Tents and Shelters
	Shelter Half, 2 Man Tent, 5 Man Tent, 10 Man Tent (Arctic), and Sleeping Gear Cold Weather.
	C. Small Arms.
	D. Crew Served Weapon
	Lightweight Company Mortar System, 60mm XM-224, 60mm M-19, 81mm M29A1, 4.2 in M-30.
CS 6	AMMUNITION SUPPLY POINT
	Small Arms Ammunition, Mortar, Howitzer, Artillery Projectiles, Rockets, Missiles.
CS 7	TACTICAL POL
	A. Bulk Storage (Includes Tank Farms, Manifolds, Pumps, etc.)
	Tank, Fabric, Collapsible, 1250 BBL, 10,000 and 50,000 Gal Bolted Steel Tank 10,000 BBL.
	B. Pumps
	6" and 8" Diesel Driven; 50, 100, 350 GPM, 6 in. 2 Stage Pipeline Pump; 6" and 8" Flood and Transfer, 8" High Pressure Turbine Driven.
	C. Pipelines
	6" and 8" Lightweight Coupled; 6" High Pressure Hoseline; 6", 8" and 12" Fiberglass Reinforced Line.
	D. Fuel Dispensing Systems
	CL III Supply Point, 12 Point Helicopter Fueling System, Airfield Refueling System.

DESIGNATION	ITEM/SYSTEM
	E. Laboratories (Fuel Analysis) Lab, Airmobile, Aviation Fuel (Semi-Trailer).
CS 8	AIRCRAFT - SUPPORT A. Helicopter Cargo Transport CH47 (Chinook) Series, CH54 Series B. Heavy Lift Helicopter (HLH)
CS 9	TACTICAL BRIDGES A. Mobile Assault Bridge (20 ft). (Floating) Armored Veh Launched Bridge (60 feet). Bailey Bridge B. Ribbon Bridge (Floating). Med Girder Bridge (MGB) 100 ft. Class 60. Armored Veh Launched Bridge (90 feet).
CS 10	TRUCKS - TACTICAL AND LOGISTICAL 1/4T, 1-1/4T, 2-1/2T, 5T, 10T, HET, and GOER (All Body Types - Emphasis on Utility, Cargo, Dump, Wrecker, Ambulance, Firetruck, Fuel Service, Water, and Vans - Expansible).
CS 11	COMBAT ENGINEER EQUIPMENT A. Dozers Tractor, Full Tracked, Low Speed, Medium, Light Airmobile, and Sectionalized Classes. Universal Engineer Tractor (UET), FAMECE, Heavy, Medium and Light Tractors. B. Cranes 5T Rough Terrain, 20T Rough Terrain, 7-1/2T Rough Terrain, 20T Hydraulic. C. Machine, Ditching, Wheel Mtd, Rough Terrain, Parsons, Unit Rig. D. Loader Bucket 1 cu/yd, 2-1/2 cu yd, 4-1/2 cu yd.

DESIGNATION	ITEM/SYSTEM
CS 11 (Contd.)	E. Graders
	Medium, Heavy, and Sectionalized Medium.
	F. Commercial Construction Equipment (CCE)
	EXEMPT - except for items forecast for issue to combat units in forward areas.
	G. Water Purification Equipment
CS 12	DIVISION SUPPORT COMMAND
	A. Shops, Shelters, Tents
	Shops, Contact Maintenance, Electrical Repair, Electronic Repair, Gen Purpose Repair, Hydraulic Repair and Other.
	Shelters - Kitchen 8x8x20 ft.
	Tents - Small, Med, Large, Extra Large
	B. Containers - Shipping and Storage
	MILVAN, Ammo 8x8x20, Optimized, Family of Ammo Containers, Dry Cargo 8x8x20, Refrigerated Cargo 8x8x20.
	TRI-CON, 8x8x6-2/3, 4x8x6-2/3, and 8x8x40 feet.
	C. Materiel Handling Equipment
	Rough Terrain Fork Lift or Fork Trucks 2,500, 6,000, 10,000 and 15,000 lb cap, Rough Terrain Crane 50,000 lb cap, Cargo Handler (Man-Amplification) 60T capacity.
CS 13	ARMY WIDE ITEMS (HIGH SIGNATURE)
	Engine Generators, Gasoline Engine (0.5 to 10 KW).
	Engine Generators, Diesel Engine (15 to 60 KW)
	Antennas - Radio or Radar (Mast, Aerial, or Dish).

DESIGNATION	ITEM/SYSTEM
CS 13 (Contd.)	Kitchen, Field (and Immersion Liquid Heaters).
	Shower Units, Field (with Heaters).
	Engine Generators, Gas Turbine (10 to 60 KW).
	Air Scatterable Land Mines, Special Ammunition.

2.5 REFERENCES

1. Regulation, AMCR 70-58, 24 January 1973, Camouflage Research and Development for Army Materiel.

2. Letter, AMCRD-GP, AMC, 13 February 1974, "Designations of Items and Systems as Camouflage Critical (CC) or Camouflage Sensitive (CS)."

3. Letter, AMCRD-SE, AMC 11 Dec 1975 Revised Camouflage Critical (CC) and Camouflage Sensitive (CS) Listings.

SECTION 3

THREAT ASSESSMENT

3.1 BATTLEFIELD INTELLIGENCE

The first step in winning the land battle is seeing the battlefield. Field commanders require intelligence to win, and they, therefore, allocate high priority and significant resources to obtain battlefield intelligence. Camouflage assists in defeating this effort by concealing truth.

Intelligence is the product resulting from the collection, evaluation, analysis, integration, and interpretation of all information concerning one or more aspects of foreign countries or areas, which is immediately or potentially significant to the development and execution of plans, policies and operations. Camouflage impacts on the intelligence process by affecting the evaluation, analysis, and interpretation of information collected.

3.1.1 The Threat

A determination of the threat results from the application and extension of intelligence using the threat analysis process. The *threat* is a potential enemy's capability to limit or negate mission accomplishment, or to neutralize or reduce the effectiveness of a current or projected item/system. The threats to camouflage are the hostile surveillance and target acquisition systems which are projected to be on the battlefield at a specified time. Specifically, camouflage must combat a potential enemy's effort to obtain militarily significant battlefield intelligence and enhance battlefield survivability.

It is useful to consider surveillance and target acquisition threats separately because they have significant differences. Surveillance consists of observing an opposing force for the purpose of obtaining information about force disposition, composition, readiness state, lines of supply, etc. Target acquisition is the detecting, recognizing, identifying, and locating of specific item/systems which become targets. Target acquisition denotes imminent peril for the item/system which has been acquired, and therefore, deserves the highest priority countermeasure effort. Surveillance threats may represent a very serious over-all problem, but there usually exists a time lag of at least several minutes to hours between detection and response based on the intelligence derived from this detection.

The camouflage task to defeat surveillance is more difficult than defeating target acquisition for a number of reasons. The surveillance function typically will have greater resources such as a greater variety of more sophisticated sensors and processes, better facilities, more time, greater foreknowledge, rested and more specifically trained personnel, etc. It is also noted that a target acquisition system may or may not have a human in

its data processing loop, whereas the surveillance system invariably will contain a human interpreter, analyser, etc. This affects the flexibility which is available in the countermeasure response.

Camouflage is primarily concerned with defeating target acquisition as a fundamental point of survival, because camouflage is more effective in this role than in combatting surveillance. Effort expended on camouflage will, however, be helpful in countering the surveillance threat.

3.1.2 Background

Threats, and camouflage responses to them, undoubtedly have their origins very far back in time but, beginning with the introduction of aircraft earlier in this century, surveillance and target acquisition threats escalated exponentially in many ways. These include the development of new platforms such as manned aircraft, satellites and remotely piloted vehicles (RPV's), and new sensor technologies such as night vision devices, lasers, radar, thermal imaging, and many more. These sensor threats represent areas of continuously accelerating technology.

Camouflage has responded with technology improvements too, such as incorporation of radar scattering properties and chlorophyll simulating pigments into screening materials. Undoubtedly, developments in materials and techniques will continue to emerge. This dynamic and changing relationship between sensor threat and camouflage technology must be recognized, forecast, and factored into decisions which are being made for the future.

Within the context of sensor technology developments alone, it may appear that camouflage is a useless and unrewarding pursuit, but the fact remains that no chain is stronger than its weakest link, and sensor technology is only one of several links in the chain which leads to battlefield intelligence. Sensor capability to produce imagery which can isolate one object from another has far exceeded its ability to provide signature data sufficient for making militarily significant identifications beyond the mere presence or absence of simple objects. Identification must still depend on the weaker link of analysis.

3.2 THREAT INFORMATION AVAILABILITY

3.2.1 Sources of Intelligence

The primary source of information on enemy surveillance and target acquisition threats is the Foreign Intelligence Offices (FIO) which are located at each major subordinate command and laboratory. The item/system developer should contact his local FIO to obtain a validated threat for his item/system. The local FIO is the single point of contact between the Materiel Developer and the intelligence community. Army Regulation 381-11 and DA Pamphlet 381-14 (References 1 and 2) contain information about the FIO system.

Threat overview documents which summarize and comment upon the present and forecasted capabilities of enemy systems and include estimates of the impact of these capabilities on existing weapon systems are notable sources of information. These are *Current Summaries of the Threat (CST)* such as MERDC-FIO-CST-1-74, FIO-CST-1-76, and MI-FIO-T-1-75 (References 3, 4, and 5) obtainable from the local FIO. More detailed information is available from the resource documents upon which the CST's were based. Some of these are listed as References 6 through 12.

3.2.2 Mirror Image

The estimation of enemy capability in any desired time period is imprecise at best. The confidence factor associated with some intelligence data may be low, and in many cases, information is completely lacking. In the absence of reliable information on enemy capability, the mirror image approach sometimes can be used wherein the enemy is assumed to have a capability equal to that achieved by the U.S. Such an approach is probably better than assuming that the enemy has no capability in the area in question, but there are two dangers built into this approach.

The first danger is that the U. S. capability is assumed to be better than that of the enemy, and that countering the U. S. capability ensures countering the enemy's capability. This ignores the possible reality of technological surprise that may occur when an enemy capability is more advanced than U. S. capability. (Sputnik is a familiar example.)

The second danger is that enemy development is assumed to pursue the same paths and goals that comparable U. S. development pursues. Development goals are choices among closely competing alternatives based upon particular value standards which vary from culture to culture. The enemy may achieve the same effectiveness with a low technology-high redundancy system as the U. S. achieves with a high technology-low redundancy system. These considerations of historical and cultural perferences should be carefully factored into any mirror image assumptions.

Catalogs of U. S. equipment may be consulted for assistance in using the mirror image approach. The *Catalog of Surveillance, Target Acquisition, Night Observation Equipment and Systems (STANO)*, is listed as Reference 13.

3.3 THE THREAT ASSESSMENT PROCESS

The information obtained from the FIO, mirror image analysis, or other sources must be examined with reference to the equipment developer's item/system to determine what type camouflage, if any, is required. This assessment must compare the capability and postulated intention of projected hostile forces with proposed doctrine, mission, and expected physical/chemical attributes and characteristics of the friendly item/system.

The Camouflage Laboratory at MERADCOM, Fort Belvoir, Virginia, is available to assist the user of this Guide with the threat assessment. Although the equipment developer has overall responsibility for the implementation of camouflage into equipment, one mission of the Camouflage Laboratory is to assist the Developer in this effort. Such assistance can be provided at any negotiated level of effort ranging from minor consultation to complete threat assessment.

There are many paths that such an analysis might take, but one is suggested by Figure 3-1, which describes a stepwise screening and matching process that will identify the sensors and signatures which may require countermeasures. At any level in the process, a negative conclusion will terminate the process whether it be expressed as "minor," "insignificant," or simply "no." Only an unbroken series of positive conclusions can lead to countermeasure implementation. Each identified sensing means should be evaluated at Level I, and if an affirmative conclusion results there, each identified sensor type should be evaluated at Level II and higher levels so long as it remains classified as a potential threat.

Although the weakest link in many surveillance and target acquisition systems is the human operator, the first pass through the threat assessment process should take the conservative approach of discounting human failures. This is another way of saying that in the initial stages of threat assessment it is safer to assume, for example, that if the item/system is visible on the photograph, it will be seen by the human interpreter even though there is some probability that the interpreter will overlook some items of interest.

The terms *detection, recognition, identification,* and *location* are used frequently in discussing the capabilities, purposes, etc. of remote sensors and camouflage. These terms are relevant to the threat assessment process.

"Detection" refers to the first indication of the presence of strange, man-made, or suspicious activity, materiel, personnel, etc. It might be a glare, a flash of light, a regular appearing shadow, a faint noise, tracks, fresh dirt, etc. that revealed nothing of the nature of what is perceived, but serve to alert the enemy to intensify his examination of a specific locale. This more concentrated search is often more difficult to defeat than the more routine scanning type search and leads to "recognition," e.g., the presence detected is eight trucks pulled off the road into a wooded area. "Identificiation" refers in part to the further conclusion that the presence (trucks in the above example) is a friend or foe.

"Location" means to fix the position of a target with sufficient accuracy to deliver effective weapons fire. It results from detection, and is affected more by "operational" than any other type of camouflage. For instance, avoiding landmarks or prominent geographic features which can serve as points of reference in communications between enemy observers and pilots or gunners.

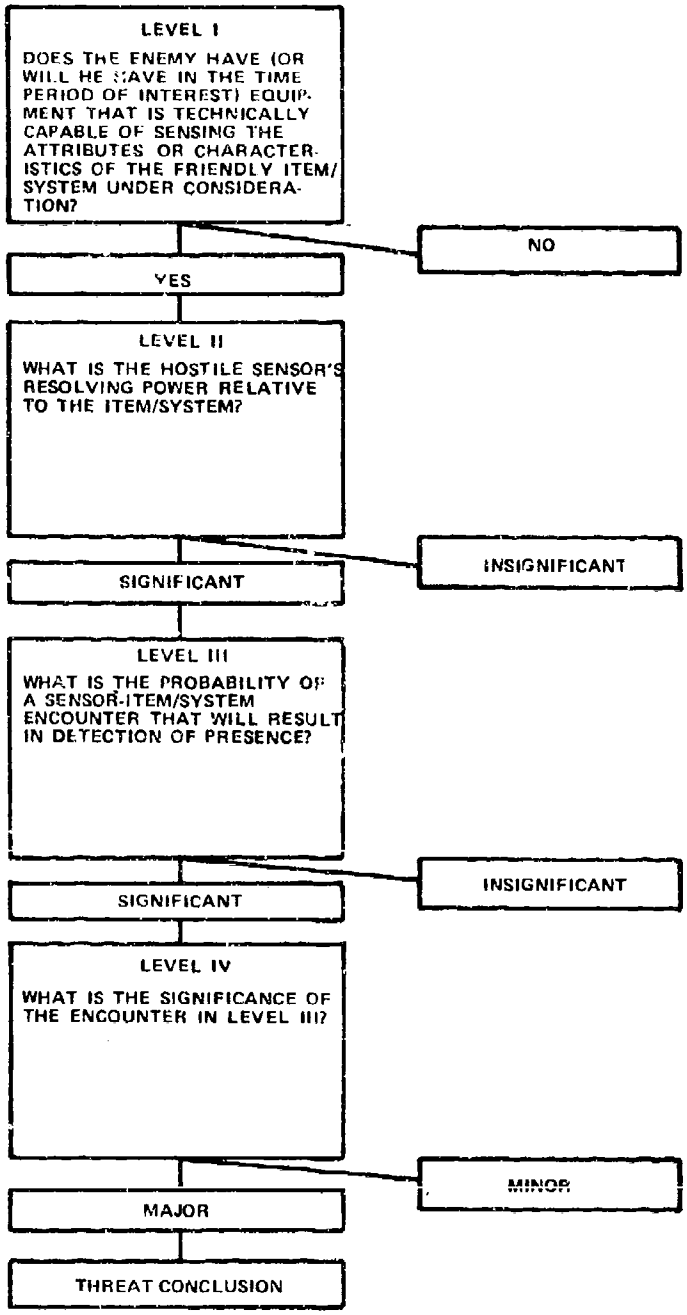


Figure 3-1 The Threat Assessment Process

In many cases, Detection, Recognition, Identification & Location will be obtained simultaneously, or combinations may be obtained simultaneously. Recognition and identification are good examples wherein once the item/system is recognized as a truck, the truck type is often apparent -- and hence identification. Perhaps identification may be inferred from location, but these factors are not necessarily so and depend on individual situations. For example, friendly equipment may or may not indicate friendly occupants.

The threat assessment must account for these graduations in the sensing system's capability. These gradations are real possibilities, and do represent a threat hierarchy in that detection of presence may not be as damaging as recognition or identification.

Each of the levels shown in Figure 3-1 is discussed in detail in this section.

3.4 REMOTE SENSORS

Fundamental to the process of assessing and countering hostile surveillance systems is the understanding of the principles of their operation, including remote sensors and their capabilities and limitations. Such an understanding is necessary for effective communication with both the FIO and remote sensor specialists. The camoufleur's objective in gaining knowledge about remote sensing systems is to know how to defeat, degrade or confuse them, and this in turn limits the amount of information needed; i.e., once the camoufleur knows which remote sensing systems are threats and how they can be defeated, he need no further information about them.

Since remote sensing systems tend to be complex systems, involving a number of elements and processes, it is prudent that the various links in the system be explored so that the weakest or most easily affected link can be determined, exploited, and defeated. Likewise, defeating remote sensing systems can be costly and time consuming, and therefore should be attempted only when it has been determined with high confidence to be a threat. This determination is facilitated by having good information.

The following facets of remote sensing systems are relevant to the basic questions of: "Can I be seen (detected, recognized, identified, and located)? If so, what is the consequence to me, and if it is of consequence, what can I do to prevent it?"

3.4.1 Remote Sensing Means

Basic to a sensor's principle of operation is the physical means by which information is conveyed to the remote sensor from an object. These means subdivide into four primary types:

1. Electromagnetic
2. Mechanical
3. Chemical
4. Field Effects

Electromagnetic radiation is the most widely used energy for sensor input. This encompasses energy ranging from gamma rays on the high end of the frequency range (Figure 3-2) to radio and inductive waves on the low frequency end and includes visible light, ultraviolet, infrared and microwave spectral regions. Electromagnetic radiation interacts with matter in ways described as reflection, transmission, refraction, absorption, and scattering. Within the limits of interest to tactical camouflage, electromagnetic radiation follows line-of-sight and obeys the inverse square law. Human sight is sensitive to only a very small window (0.38 to 0.78 micrometer wavelengths) in the electromagnetic spectrum. Other sensors respond to radiations outside the visual range, some being sensitive to a single frequency, and others being sensitive to both narrow and broad bandwidths. Descriptions of these radiations usually include frequency, intensity, and a title such as visual, infrared, etc. Electromagnetic remote sensing means are a major concern for camouflage.

Mechanical wave propagation is divided into two subdivisions, sonic and seismic. Mechanically induced waves originate by a physical vibration which imparts energy to the transfer medium, usually air for sonic and earth for seismic waves. These waves travel through the medium, being modified by the variations within the medium, such as density, temperature, etc. Descriptions of these energies usually include their frequency or wavelength, amplitude and phase. Although sensors that rely on mechanical energy transmissions for input are of some interest, they are presently classed as moderate threats, except for artillery.

Chemical transfer is an atmospheric dispersion process. Chemical transfer normally is of minor importance compared to electromagnetic and mechanical energies but where used, it may be critical. It involves the dispersion of small droplets of a substance or the escape of free molecules which disperse throughout the atmosphere because of thermal motion or wind effects. Chemical effects descriptors include the molecular formula for the chemical, its volatility, and concentration of free molecules within a given space.

Field effects include magnetic, electrical and gravitational field when used for detecting shifts or anomalies in the strength, or intensities. These are not of major importance in battlefield situations.

The basic means used for remote sensing are shown in Figure 3-2. Some of those are not of significant military interest as battlefield remote sensing means. Radio and induction are within the field of electronic warfare rather than camouflage. Other remote sensing means are listed in Table 3-1, along with a general listing of the attribute or characteristic (detection cue) of an item/system which they sense. For many item/systems the Level I screening of threats according to remote sensing means will not screen out anything, but for others some remote sensing means will drop out as inapplicable.

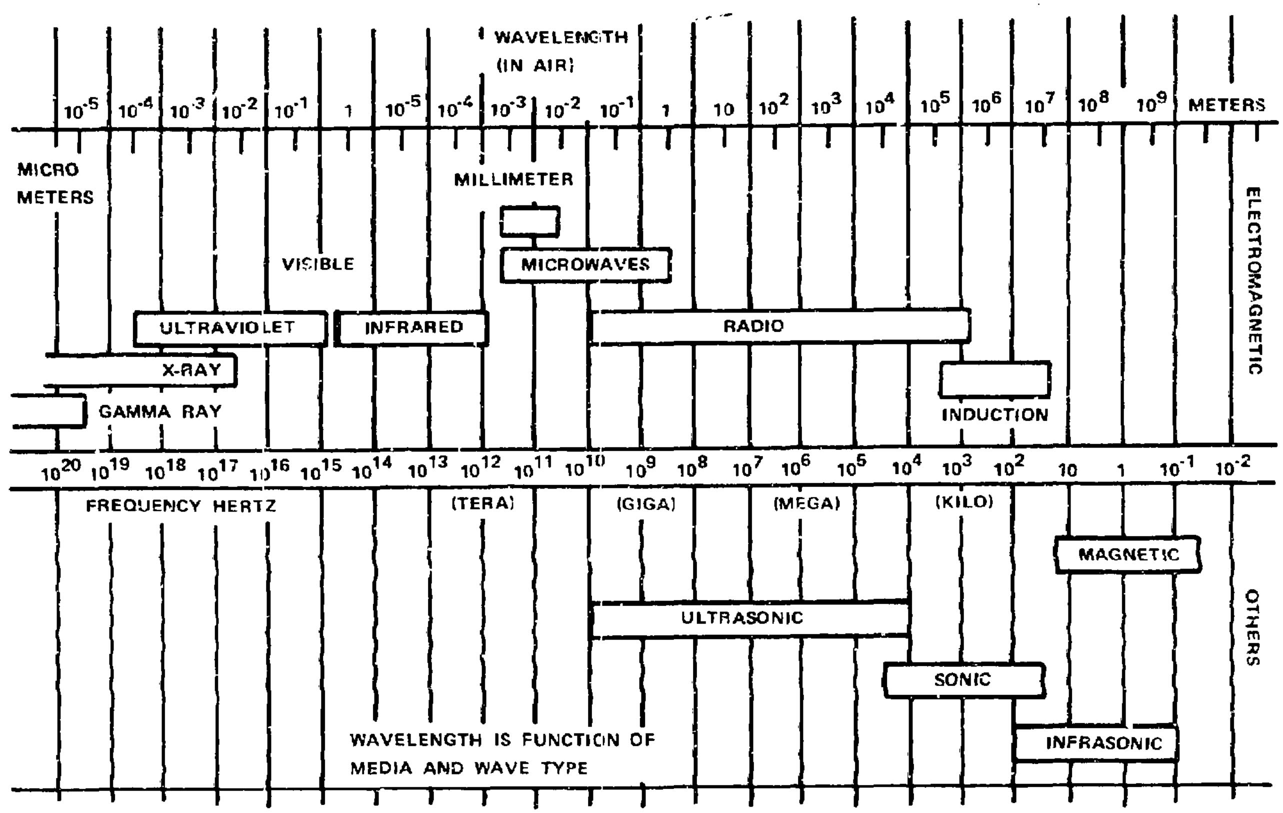


Figure 3-2 The STANO Energy Spectrum

Table 3-1

REMOTE SENSING MEANS AND DETECTION CUES
(LEVEL I)

DETECTION CUES	REMOTE SENSING MEANS
Configuration (1, 2, 3, 4)*	1. Visible light
Visible light emissions/reflectance (1)	human vision (unaided)
Ultraviolet emissions/reflectance (2)	human vision (aided)
Infrared reflectance (3)	photography
Infrared emissions (3)	2. Ultraviolet
Microwave reflectivity (4)	3. Infrared
Noise sources (6, 7)	4. Microwave
Electrical properties (4, 8, 9)	5. Electromagnetic pulse
Mass (7, 8, 9, 10, 11)	6. Sonic
Speed (4, 6, 7, 8, 9, 10, 11)	7. Seismic
Exhaust emissions (3, 5)	8. Magnetic field
	9. Electromagnetic field
* Number indicates the Remote Sensing Means (right column) which Sense this Detection Cue	10. Force
	11. Deformation

3.4.2 Remote Sensor Characteristics

Identified remote sensing means which may be threats to an item/system merit further examination to determine the hostile sensor's resolving power relative to the item/system. Examination of this subject should be based upon the assumption that the sensor is operating and looking at the item/system, and that the item/system is emitting the remotely sensed energy or displaying the sensed attribute; i.e., the sound detector is operating, is properly positioned and pointed, and the item/system is generating sound. Questions of interest at this point are: "At what range and condition can the item/system be sensed and to what degree?" The format for the answer to this type of question is displayed by the graph shown in Figure 3-3.

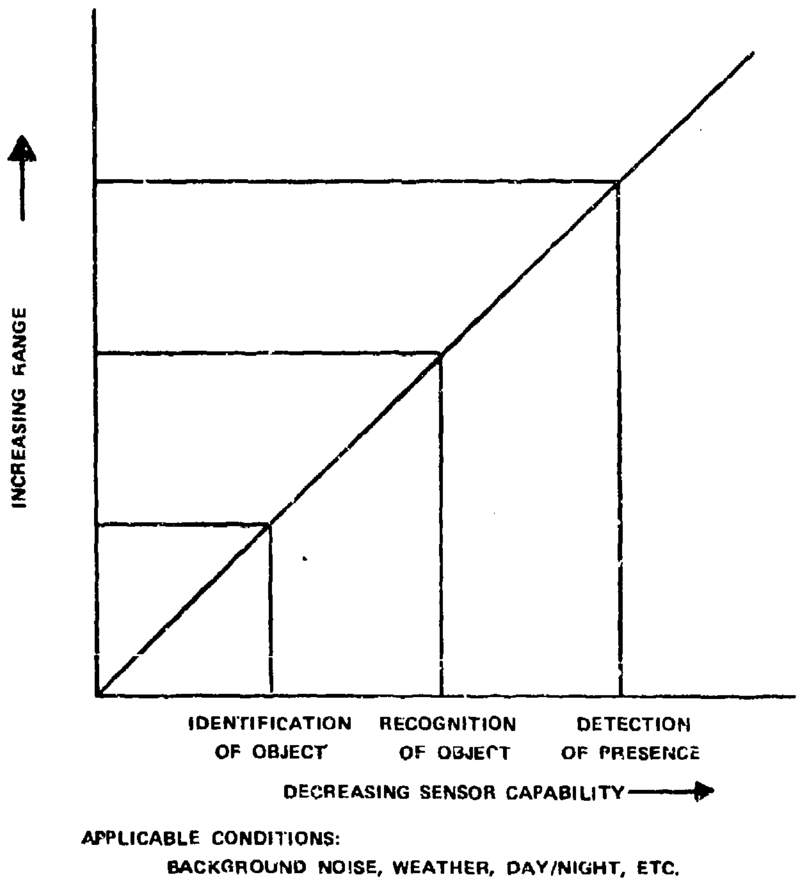


Figure 3-3 Threat Assessment, Level II, Information

The generation of data of the type illustrated by Figure 3-3, requires a substantial amount of input about both sensor capability and item/system signature cues. These subjects are discussed in the following pages.

In reviewing the various remote sensors and their characteristics, it is well to keep in mind the various item/system attributes and characteristics that act as signature cues for remote sensors. Some of these are listed in Table 3-2.

Table 3-2

ITEM/SYSTEM SIGNATURE CUES

Size
Shape (profile, shadow casting, straight lines, etc.)
Spectral reflectance
Luminance contrast
Motion
Emissivity
Surface temperature
Radar cross-section (flat, metallic surfaces)
Acoustic intensity and frequency (characteristic pattern)
Electromagnetic pulse intensity and frequency
Mass

The prime operational characteristics of battlefield remote sensing systems are effective range, resolution, spectral region of operation, and sensitivity.

The effective range for a given sensor depends upon the target-to-background contrast, the signal strength involved, and the transmission losses. An effective range specification is an indication of a safe standoff distance in an encounter between a sensor and a target beyond which the sensor most likely will not detect the target. This range, in combination with the range of the sensor platform, indicates those areas of the battlefield where detection by the sensor is possible. As an example, most short range sensing systems will be encountered throughout the battlefield while satellite-borne sensors are effective worldwide. Camouflage is effective in decreasing the effective range of remote sensors.

Resolution is a measure of the detail of some phenomena or scene that a sensor system can indicate or display. Increased resolution capability of a sensor system gives the interpreter more information to consider and, hence, requires an increase in camouflage sophistication to deny identity cues.

The resolution element, of an imaging type sensor with a raster scan or television type display, is the scan line spacing. A typical relationships between recognition probability or identification probability and the number of scan lines across images of military vehicles is shown in Figures 3-4 and 3-5. (Reference 14).

Statements of the sensitivity of a system indicate the minimum target-to-background contrast that can be detected. These are usually statements of noticeable differences in apparent temperature, radar cross section, color, shape, speed, depth, distance, etc.

Remote sensing systems operate only in narrow bands of the electromagnetic spectrum. Knowledge of these bands aids the camoufleur since the target needs to match the characteristics of the background in only that band to defeat the sensing system. For example, camouflage detection film is used for wavelengths in the 0.6- to 0.9-micron band so that camouflage to defeat this film need match the background only in this band. In particular, military coatings need to match the reflectance of chlorophyll in the 0.6- to 0.9-micron band; the difference in reflectance between the coating and chlorophyll is of no interest outside this band.

Some missile seekers are sensitive to a narrow band of near-infrared radiation and are attracted to reflected sunlight. The camouflage to defeat these seekers is a coating with low reflectance in this band. The visual color of this coating is of no consequence to the seekers since the seekers cannot "see" in the visual band.

The general procedure for determining the camouflage treatment of an item/system against a sensing system is to separately investigate the item/system and the background with instruments sensitive to wavelengths in the band of interest. Differences should be minimized by the camouflage treatment.

3.5 SIGNIFICANT SURVEILLANCE AND TARGET ACQUISITION SENSORS

Reconnaissance and observation of the enemy can be broadly categorized into three areas: (a) long term surveillance, (b) short term surveillance, and (c) target acquisition. The ultimate purposes of the combination of surveillance and target acquisition are to detect, recognize, identify, and locate "targets" to achieve a particular military objective. Although all sensor systems are fundamentally the same, whether intended for surveillance or target acquisition, there are subtle differences with respect to the timeliness of the intelligence indicators and the primary function of a particular system. For example, one of the functions of a surveillance system is to prevent tactical surprise by detecting, identifying and interpreting attack indicators. This is contrasted with a target acquisition system, whose primary functions are to detect, identify, and locate a target in a combat environment so that a weapon can be accurately delivered.

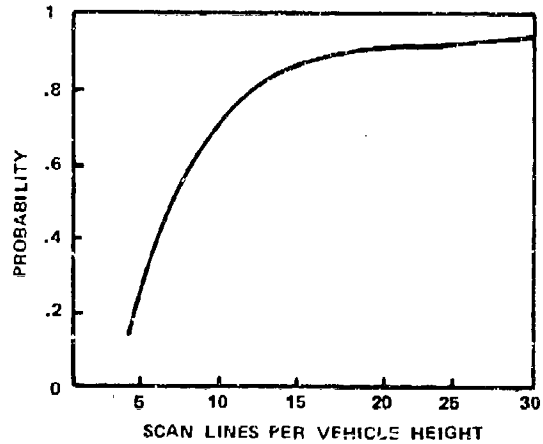


Figure 3-4 Probability of Identification Versus Lines per Vehicle Height

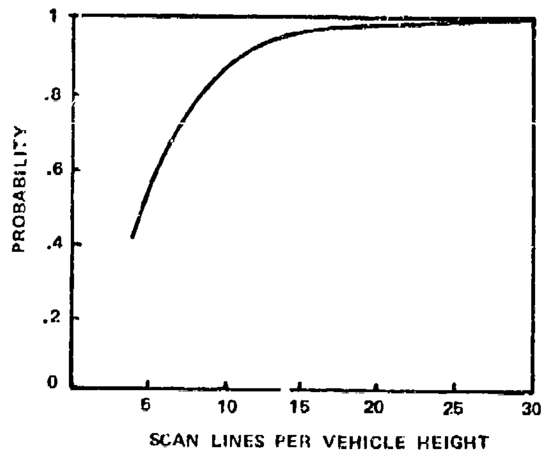


Figure 3-5 Probability of Recognition Versus Lines per Vehicle Height

The purpose of long term surveillance is to obtain sufficient information well in advance (days or more) so that necessary actions can be taken which will effectively counter any changes or new developments, such as in force concentration. Also important to long term surveillance is the identification of new construction and/or large scale troop/materiel movements. Long term surveillance is customarily performed at long range with high-resolution sensors on satellites, aircraft, or drones. Short term surveillance on the other hand, usually takes place in time of war where the need is to recognize and identify shorter term (hours to minutes) tactical enemy targets such as artillery, small-scale troop movements, or other objects for subsequent short-term combat engagement. In this application unconventional sensors, such as unattended ground sensors (UGS) and remotely piloted vehicles (RPV's), may play increasingly significant roles, along with the more conventional reconnaissance sensors.

The main purpose of target acquisition is to determine accurately the location, on the ground or in the air, of military targets for immediate destruction (minutes to seconds) by firing a weapon and is thus viewed as an "in combat" or battlefield action. In recent years, airborne attack sensor-weapon systems have found widespread use, e.g., forward-looking infrared (FLIR), low-light-level television (LLLTV) systems, and synthetic-aperture radar (SAR). Air-deliverable weapon systems, having sophisticated terminal guidance sensors, are also being developed. These include the laser-guided bombs, electro-optical guided munitions, and imaging infrared guided weapons.

General descriptions of the more significant friendly and possibly hostile surveillance and target acquisition sensors are given below. This discussion follows closely that presented in Reference 15. More details about particular hostile sensing systems will be required to answer questions of specific capability. The systems described are as follows:

- Vision
  - Unassisted
  - Assisted
    - Binoculars, Periscopes
    - Night Vision Devices
    - Low Light Level Television

- Photographic
  - Ultraviolet
  - Black and White Film
  - Infrared Film
  - Camouflage Detection Film
  - Color Film

- Infrared
  - Line Scanners
  - Forward Looking Radar (FLIR)

- Laser
  - Target Designators
  - Rangefinders
  - Scanners

Microwave
- Side Looking Airborne Radar (SLAR)
- Synthetic Aperture Radar (SAR)
- Battlefield Surveillance Radar
- Moving Target Indicator (MTI)

Unattended Ground Sensors
- Acoustic
- Seismic
- Magnetic
- Electromagnetic
- Infrared
- Pressure
- Strain

Indirect-Fire Locating Systems
- Sound
- Flash
- Electromagnetic Pulse

3.5.1 Unassisted Vision

The human eye is undoubtedly the most effective means for detecting, recognizing, and identifying targets, not only because of the intelligence and analytical capabilities furnished by the brain, but also because of the superior resolution capability, field of view, and dynamic range. The eye has an approximate angular resolution of 1 to 3 minutes (0.3 to 0.9 miliradians), a field of view of 120°, and a dynamic range of nine decades of illumination (10^{-6} to 10^{3} candles per square meter). These are combined capabilities which have never been matched by any other sensor.

Under certain controlled conditions, the human eye will respond to radiant energy from the near-infrared to the near-ultraviolet, but the visible spectrum is usually considered to extend from 0.38 to 0.78 microns. Variations in wavelength are manifested by changes in color, i.e., the violets are at 0.40 microns, blending into the blues at 0.45 microns, greens at 0.50 microns, yellow-orange at 0.60 microns and reds at 0.63 microns and longer. The peak response of the human eye occurs in the yellow-green band (0.555 micron for a light adapted eye and 0.515 for a dark adapted eye), a fact of obvious importance to a camouflage system developer.

Whether or not a target can be detected by the eye depends upon many factors. An indication of the complexity of this problem and a partial solution to the practical estimation of the visual range is given by the nomogram in Figure 3-6 (Reference 16). Here, the visual range is related to: The area of a target (resolution considerations), the luminance-contrast between the target and the background (sensitivity considerations), the visibility or the meterological range of the atmosphere, and the luminance of the background.

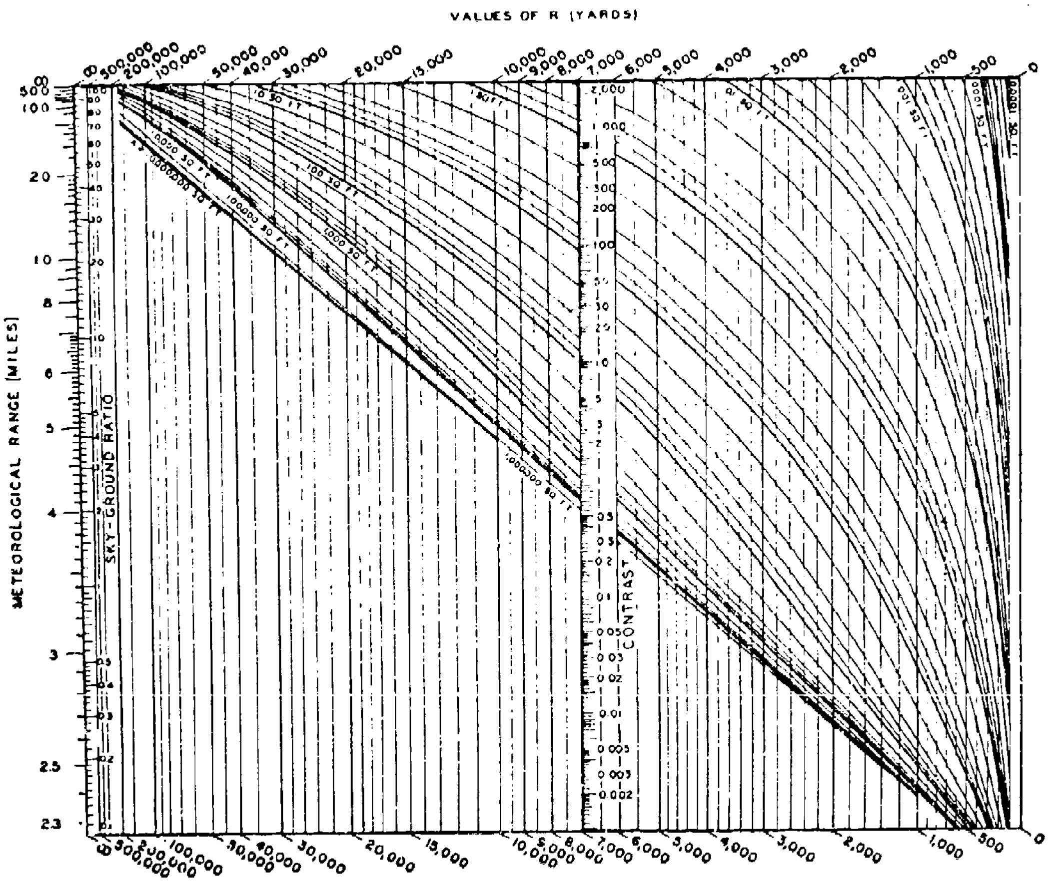


Figure 3-6 Sighting Range in Yards of Circular Objects on the Ground, Seen from the Air in Full Daylight, Based on the Tiffany Data for Circular Targets, at a Probability of Detection of 95 Percent

The luminance contrast, C, is defined in terms of luminance (brightness) of the target, T, and of the background, B, by the equation:

$$C = (T-B)/B = (R_T - R_B)/R_B.$$

The contrast ranges from -1 for a black target on a white background to large positive values for bright targets against a dark background. Contrast may be measured by a photometer or may be estimated from knowledge of the reflectance, R, of the target and of the background. Contrasts greater than

2 to 5 are unusual (Reference 17) unless the target reflects sunlight specularly or the background is very dark.

The luminance of the background is taken into account by the sky-ground ratio, the luminance or brightness of the background relative to the sky. Typical values are given in Table 3-3 (Reference 16).

Table 3-3

TYPICAL VALUES OF THE SKY-GROUND RATIO

Sky Condition	Ground Condition	Sky-Ground Ratio
Clear	Fresh Snow	0.2
Clear	Desert	1.4
Clear	Forest	5
Overcast	Fresh Snow	1
Overcast	Desert	7
Overcast	Forest	25

Figure 3-6 strictly applies only to solid, one-color, circular targets. In general, the more deviation there is from a circular shape, the higher the contrast needed to detect a target of the same area. (Reference 18).

As an example of the use of Figure 3-6, determine the detection range of a 10-square-foot target, reflectance 0.7, against desert soil, reflectance 0.21, under a clear sky with a meteorological visibility of 30 miles and a sky-background ratio of 1.4. The contrast is given by:

$$C = (0.07-0.21)/0.21 = -0.67$$

The first step is to draw a straight line from 1.4 on the Sky-Ground Ratio scale through 0.67 on the Contrast scale. The intersection of this line with the right hand edge of the nomogram establishes a turn point. Next, draw a second line from the turn point to 30 on the Meterological Range scale. The intersection of this second line with the curved line representing 10 square feet occurs at 4200 yards on the Range scale. Therefore, the range for 95% probability of detection is 4200 yards.

This nomogram is also useful for estimating what cannot be seen at a given viewing range; e.g., visual decoys need not display surface features which cannot be seen. This nomogram can also be used to estimate the minimum area that can be detected, and surface features smaller than this will be detected with less than a 95% probability.

Reference 16 also discusses the estimation of the visual range for the following situations:

- Targets seen looking upward against the sky.
- Targets seen along horizontal paths against terrestrial backgrounds.
- Targets seen through telescopic systems.
- Targets that are light sources or are illuminated by artificial light.
- Targets that are colored.
- Targets that are viewed with a camera.

Reference 19 presents a valuable survey of the psychological literature relevant to the visual range and its prediction.

3.5.2 Assisted Vision

There are a host of sensing devices which enhance the ability of the eye to detect and identify targets. Devices such as binoculars and periscopes, image converters, image intensifiers (II), and low-light-level television (LLLTV) are representative of this class. These devices extend the observer's viewing range by forming an enlarged image of the target at the observer's eye, by extending his vision into the near-infrared region (to 1.0 micron) and to illumination levels far below normal vision capabilities, and by allowing the observer the capability of not looking at objects in front of or behind the target.

Two developments in the 20th century had a significant impact on devices such as binoculars and periscopes: (1) the application of anti-reflection coatings to optical surfaces, and (2) the use of active optical elements to stabilize the observed image in hand-held devices. Devices with coated optics have more light transmission and less veiling glare than with uncoated optics of equivalent design. This extends the observer's range into lower contrast and illumination levels. Active elements stabilize the image at the observer's eye by optically compensating for slight angular motions of the optical device caused by hand tremors and platform vibrations. This technological advance enables observers to use higher magnifications and to observe from moving platforms.

Both of these developments are positive factors in extending the operational capability of the military observer. Figure 3-7 (Reference 15) shows the angular resolution capability of present (10 to 20 power) optical devices. An angular resolution of 1 milliradian is equivalent to a resolution of 1 meter on a target 1 kilometer distant, or of 2 meters on a target 2 kilometers distant.

The dashed horizontal line indicates the expected resolution capability of the unaided eye under favorable viewing conditions such as high contrast targets and high illumination levels. The design limit of representative 10- to 20- power optical systems is indicated by the bar at the extreme

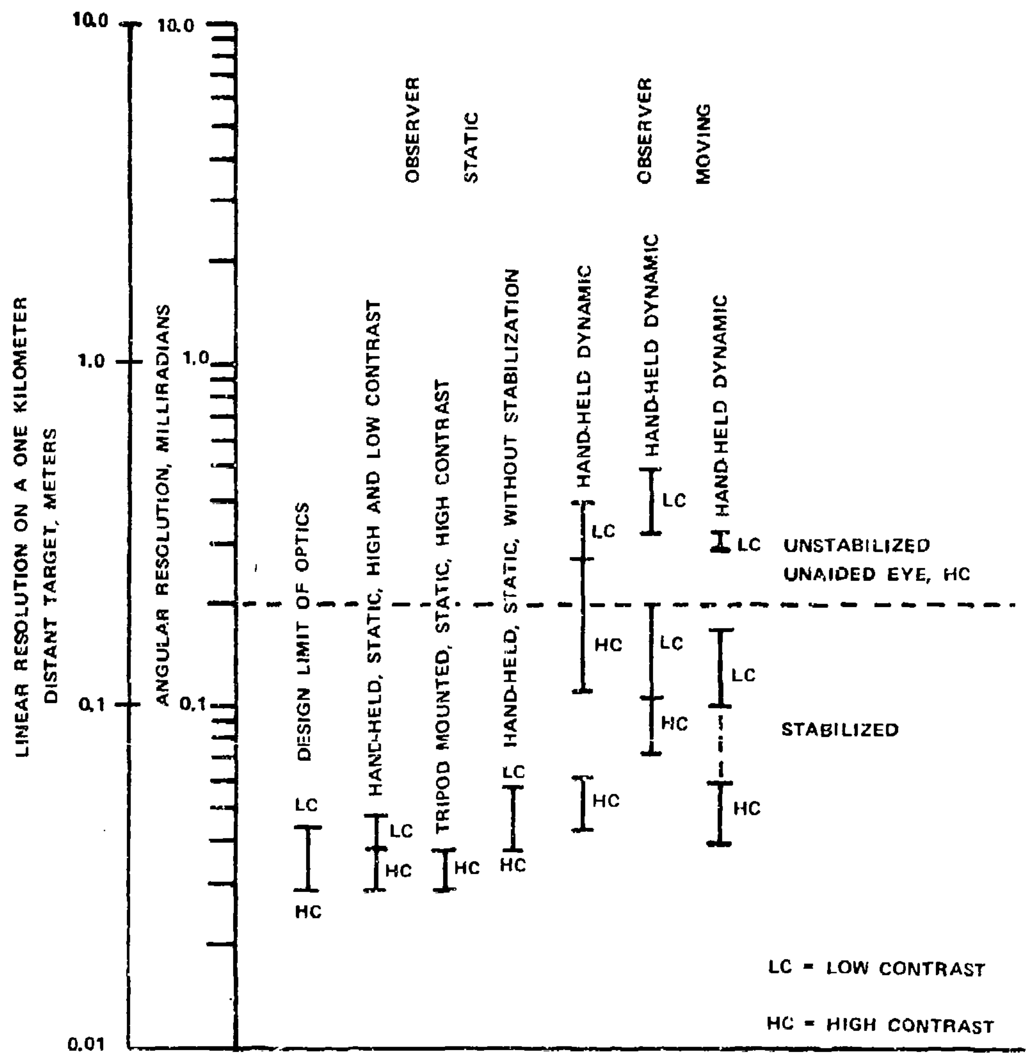


Figure 3-7 Angular Resolution for Hand-held Optics (10 to 20 Power), With and Without Stabilization

left of the diagram ("Design Limit of Optics"). The next three vertical bars indicate the measured performance of such optical systems when the observer is static. The last three sets of vertical bars at the right of the diagram indicate the measured performance of existing optical systems when the observer is standing or riding in a moving vehicle. The upper set of bars represents the measured performance in the dynamic mode of observation without the use of image-stabilization optics. The lower set of bars indicates the measured performance achieved by the use of image-stabilization optics. The improvement is significant. The three sets of data are the results achieved with three different types of image-stabilization binoculars.

The resolution of an optical device is an indication of the level of detail in a target image presented to the observer but is not, of course, an indication of the useful range of the device. As in the case of visual range of the unaided eye, the visual range of optical devices depends upon the illumination level on the target and background, on the acuity of the observer and related psychological factors, and on the transmittance of the atmosphere.

The relationship among the angular resolution of a device, the range from the device to a target, and the linear resolution on the target is shown graphically in Figure 3-8.

Figure 3-9 represents the measured detection range of a camouflaged M60A1 tank in a simulated European scenario as viewed by unaided and binocular-aided vision (Reference 20). As can be seen from the test data, the use of binoculars has increased the range of 50 percent probability of detection from 750 meters to 1350 meters and has increased the probability of detection at 1000 meters from 24 to 75 percent.

Probably the first infrared imaging device put into production was the hand-held metascope, which made use of a rare-earth phosphor to convert near-IR radiation (0.7 to 0.9 micron) to visible light. With suitable optics, a low-grade image of a nearby infrared-illuminated object could be formed. The metascope could also be used to detect radiation from infrared searchlights or vehicle night-driving lights. Metascopes currently employ an improved infrared-to-visible image converter tube and include a light source and infrared filter to permit map reading and other close-range activities.

Helmet-mounted infrared binoculars, using two image-converter tubes, are intended primarily as a night-driving aid. These binoculars receive reflected illumination from infrared-filtered vehicle headlights.

The Sniperscope consists of an image-converter tube, optics, and an infrared light source mounted on a rifle. The image-converter tube can also detect infrared sources passively within its field of view or make use of illumination from a remote cooperative source such as infrared xenon-plasma searchlight. Range is primarily dependent on the intensity of the light sources or the target infrared source.

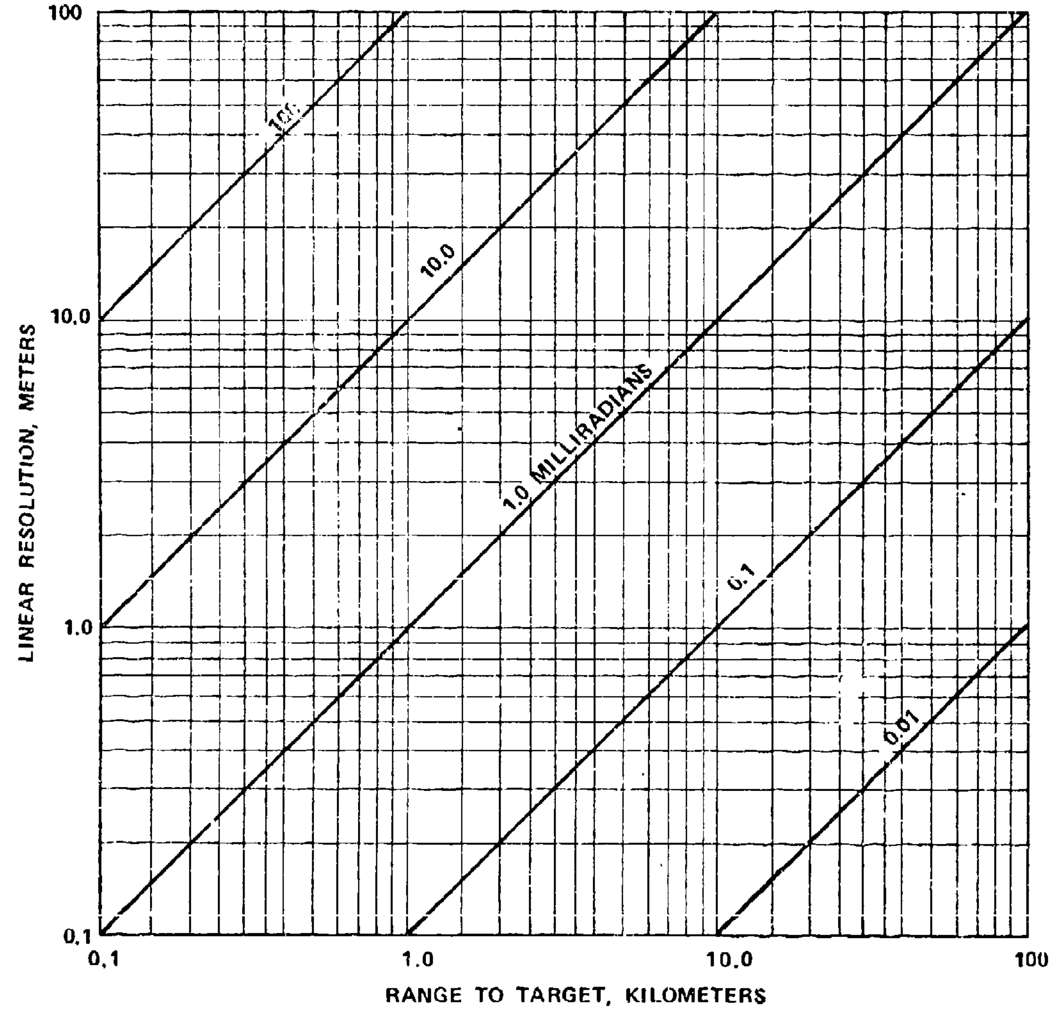


Figure 3-8 Relationship Among Angular and Linear Resolution and Range

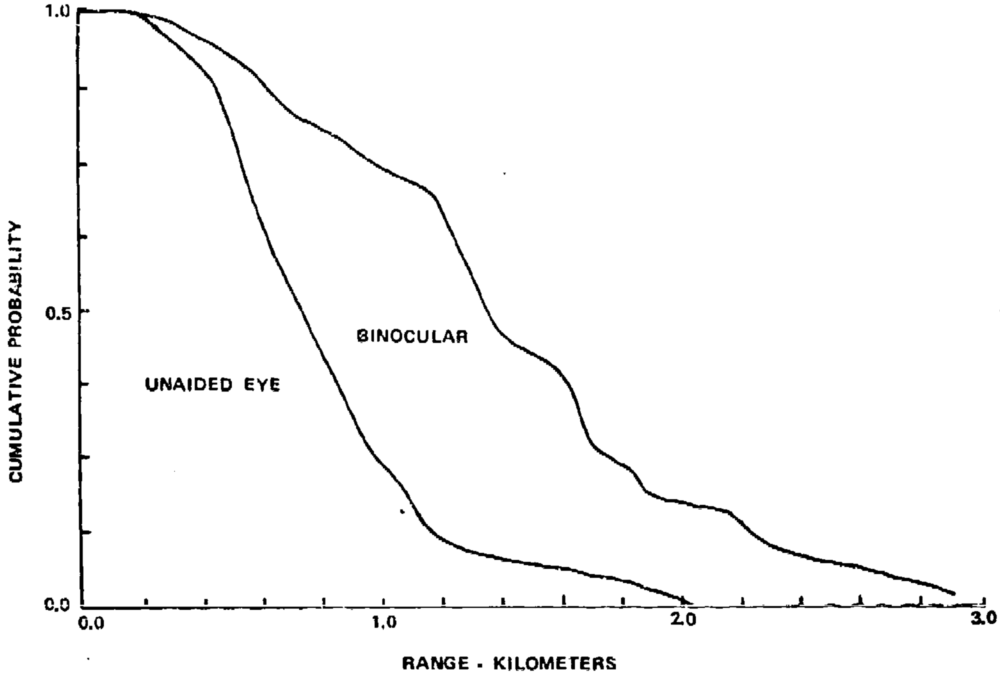


Figure 3-9 Detection Range of Camouflaged M60A1 Tank

The Sniperscope was superseded by the rifle-mounted Starlight scope. This is a direct viewing, passive imaging system using an image-intensifier tube sensitive in the visible and near-infrared as is the image converter. This equipment is effective at illumination levels as low as those from a moonless, starlit sky.

Image intensified night vision devices have been produced in increasingly larger sizes for use on light machine guns, crew served weapons, tripods, tanks, and aircraft. Smaller units, such as night vision goggles, have been developed for use by aircraft personnel flying nap-of-the-earth configurations and by ground personnel for performing various nighttime functions. Range, nominally 300 to 3000 meters, is related to the level of illumination and to the diameter of the collecting optics of the device.

When the image intensifier is coupled to a conventional TV camera tube, the assembly is known as a low-light-level television system (LLLTV). This device permits remote viewing of the intensified image on a television monitor with fidelity comparable to that of commercial television.

While image intensifiers and LLLTV systems are essentially passive, sensing night-sky radiation reflected from the target, range and target discrimination can be improved through use of an active near-infrared illuminator. In a range gated configuration, a laser illuminator is pulsed and the LLLTV receiver is activated only for the period of time when the reflection is expected from the target. This approach illuminates the target without illuminating the background or backscattering radiation from particles in the atmospheric path between target and receiver. Targets which blend into a distant background may show up as a silhouette if the range gate is set at the background distance.

Angular resolution varies with illumination level and is limited by screen quality. It is now on the order of 25 lines/millimeter permitting sensor resolutions of 0.1 milliradian or less. Due to coupling losses, the performance of LLLTV systems likely will never exceed that of the directly viewed image intensifier.

Effective range of these systems is dependent upon: target-to-background contrast, illumination, the diameter of the collecting optics (greater range for the larger systems), weather conditions (severe attenuation by fog and moderate attenuation by haze, rain, and snow), and the sensitivity of the image intensifier active surface to night-sky radiance. Reference 15 contains a plot of the approximate range of passive, near-infrared night vision devices with respect to time for the period from World War II to 1995. The classified Annex to this Guide contains a table of the average range of representative U.S. and U.S.S.R. electro-optical devices for a 90% probability of detection/recognition.

3.5.3 Photographic Systems

Simple cameras were used from balloons as early as the American Civil War and from aircraft during World War I. Relatively sophisticated cameras of large film formats, automatic exposure cycles, and interchangable lenses were used in vertical and oblique modes during World War II and the Korean conflict. Additional improvements in resolution have been realized through the continuous development of a number of reconnaissance and cartographic cameras during the last 15 to 20 years. Significant improvements in the inherent resolution of the aerial photographic camera resulted from the development of image motion compensation devices and stabilizing platforms.

Modern military photographic systems are mounted on a variety of aerial platforms. Remotely piloted vehicles and battlefield surveillance aircraft take photographs from heights of 100 meters and greater above ground level. High performance reconnaissance aircraft can take photographs from heights in excess of 20 kilometers. Satellite photography occurs at heights of 160 kilometers or more. Photography can occur at these heights subject to the restrictions of adverse weather, cloud cover, and insufficient nighttime illumination.

The resolution of the photographic image at the target is related to the height of the camera above ground level, the focal length of the lens, and the achievable resolution in the film if the limiting effects of the atmosphere are ignored.

$$T = \frac{H}{25.4\ FL}$$

T = target resolution, feet
F = lens focal length, inch
L = film resolution, lines/mm
H = target height, feet

For example, a photograph taken at 25,000 feet above ground level through a 10-inch focal length lens onto film with a resolution of 100 lines per millimeter will have a resolution on the target of about one foot.

The resolution at the target is directly proportional to the camera height. This means that low level photographs contain more detail that photographs taken at a greater height with the same camera.

Resolution varies across the photograph, and is minimum at the point directly below the camera. As in the situation shown in Figure 3-10, the resolution at the edge of a panoramic photograph (where the slant range is twice the height) is four times as large as the minimum target resolution distance.

$$T = \alpha R^2/H$$

$$T_{min} = \alpha H$$

T = Target resolution
α = Camera angular resolution
H = Camera height
R = Slant Range

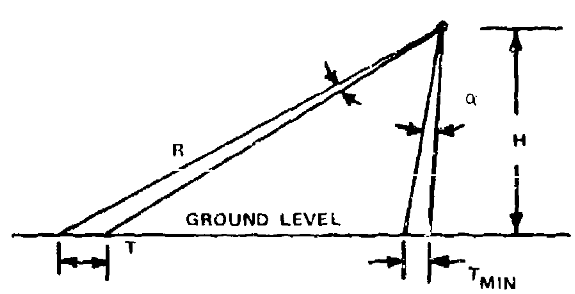


Figure 3-10 Slant Range Resolution

For example, a camera-film-processor system with an achievable angular resolution of 0.03 milliradians is flown 20 kilometers above a target. The minimum resolution is 0.6 meters. Near the edge of a vertical photograph where the range is 40 kilometers, the target resolution is 2.4 meters.

The ground coverage of a single aerial photograph depends upon: the field of view of the lens, the number of lenses in the camera, the orientation of the lens axis with respect to the vertical, and the height of the camera above ground. The field of view, in turn, depends upon the focal length of the lens and the film format. Figure 3-11 shows three typical patterns.

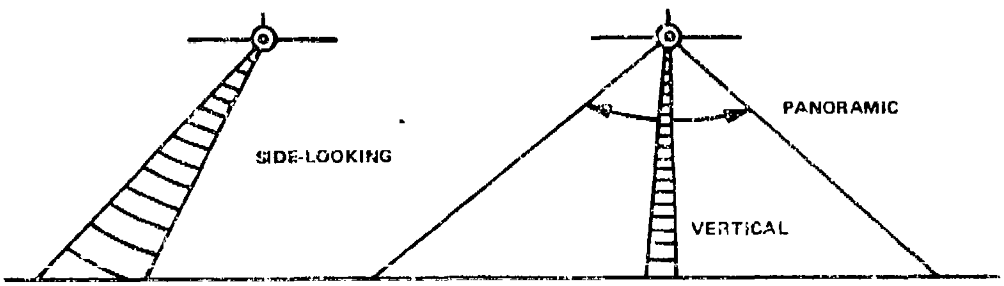


Figure 3-11 Aerial Photography Ground Coverage Patterns

There are five principal types of aerial photography:

- Black and white in the ultraviolet region (0.35 to 0.38 microns)
- Black and white in the visible region (0.38 to 0.70 microns)
- Black and white in the near-infrared region (0.70 to 0.95 microns)
- Color in the visible region only (0.38 to 0.70 microns)
- Infrared color (camouflage detection) in the visible and near-infrared region (0.60 to 0.90 microns)

Data on specific film-filter-camera combinations are available in reference manuals such as Reference 21. Ultraviolet photography and camouflage detection photography are of particular interest to this Guide and are explained in the following two paragraphs.

Ultraviolet photographs are a record of the reflectance of materials in the near ultraviolet region. It so happens that snow has a high reflectance in both the near-ultraviolet and in the visible region, while many white coatings have a high reflectance in the visual region and a low reflectance in the near-ultraviolet region. Such artificial coatings blend with a snow background in black and white and in color photographs, but may appear as black objects against a white background in ultraviolet photographs.

Camouflage detection photographs are a record of the reflectance of materials in the 0.60- to 0.90-micron region. In this region, living foliage changes from a low reflectance in the visible portion to a high reflectance in the near-infrared portion, whereas many green coatings exhibit a low reflectance in both portions. Camouflage detection film exploits this difference and records live foliage as magenta (bluish red) and low infrared reflectance materials as other colors. These other colors, in an otherwise magenta image, provide strong detection cues to artificial, man-made objects.

Unlike conventional color film which has three layers sensitized to blue, green, and red, camouflage detection film has three layers sensitized to green, red, and infrared. A #12 yellow filter (minus-blue) is used to eliminate the blue radiation which would affect all three layers. The green-sensitive layer produces a yellow positive image, the red-sensitive layer produces a magenta positive image, and the infrared-sensitive layer produces a cyan (blue green) positive image. Foliage records as red or magenta on this film because it is highly reflecting in the infrared region which produces a thin cyan image. This then allows red from the other two layers to show through strongly. Reference 22 discusses a two-color camouflage detection film.

Multispectral photography is a generalization of the above ideas to more than one or two spectral bands. If a target is spatially indistinguishable from the background in one spectral region, it may contrast with the background in another region of the spectrum and thus be spectrally detectable. Cameras for multispectral photography consist of multiple lens-filter-film combinations or a camera with one lens and multiple prism-filter-film combinations (Reference 23). Widespread use of multispectral surveillance will require that camouflage materials match the spectral reflectance of the background throughout a large region of the spectrum, not just in isolated bands within that region. Reference 24 shows examples of aerial photographic imagery.

Photographic processes can be further manipulated to secure more information. The use of color photography is well known as a means of adding additional identifying cues to objects in the photograph. This is achieved through a sacrifice in sensitivity, contrast and detailed resolution. What is not immediately apparent is that all color photography is artificial and does not reproduce exactly what is seen and therefore is a form of camouflage detection if manipulated properly. The use of so called *false color* to both enhance the separation of objects and provide identification cues is represented by the two-and three-component camouflage detection films used. These exploit areas of the spectrum which are difficult to match with

colorants. By recording these differences either on separate emulsions or by sequential filtering with a TV system and recombining them by superposition, each in a different color, the result provides an exaggerated color difference cue not readily apparent to individual images before being combined. If this is done using separate cameras or otherwise recording narrow band images it is called "spectrozonal." The ultimate in this is to record the complete spectral distribution for each image point and selectively recombine whatever sets of spectral bands are desired.

Color is also used in a pseudo way to make completed patterns of data more comprehensible, without having any relationship to the data itself. The separation of a black and white image into a selected set of contrasts, and then coloring the contrast steps in different colors permits an analysis not otherwise available. An example of this is the coloration of thermal images which show temperature - emissivity relationships through color differences. Another form involves applying arbitrary coloration to recorded phenomona such as atmospheric pressure differences or the mundane example of political divisions of a map.

The use of stereo techniques to achieve spatial separation of objects implaned is well known today. The relationship is that of parallax separation versus overlap in the field of view of two sensor paths. By increasing the separation of image forming optics while keeping the scene overlapped (usually about 60%) as shown in Figure 3-12, exaggeration in apparent depth is achieved. Optical range finders work on the same parallax basis. This ability to separate objects spatially was used as a cue in discovering flat top camouflage screens which otherwise blended well. One would see a patch of terrain that for no apparent reason was floating above the ground. The use of drape screening systems, if installed properly, brings the terrain over the object in a hill-like fashion which is less likely to be noticed through the stereo technique.

The technique of flickering alternate images of a given area or object to reveal differences is closely allied to the combination technique reviewed in the discussion of color. It consists of alternately presenting to an observer first one, and then a second image. By optically superimposing these images of some scene taken at different times, any differences which have taken place are quickly revealed and a flickering is noted -- from whence it gets its name. If a negative-positive combination is used and the light is balanced, that which has not changed will be cancelled out, and the detection cue is that only those objects which have been moved within, introduced to, or eliminated from, the scene will be evident.

3.5.4 Infrared Systems

Passive infrared (IR) sensors for use in surveillance and target acquisition roles are image forming systems which sense radiation emitted by objects within the field of view (FOV) of the system. This radiation usually is spectrally continuous over the entire electromagnetic spectrum, but is not constant in magnitude. The intensity of the radiation and the wavelength

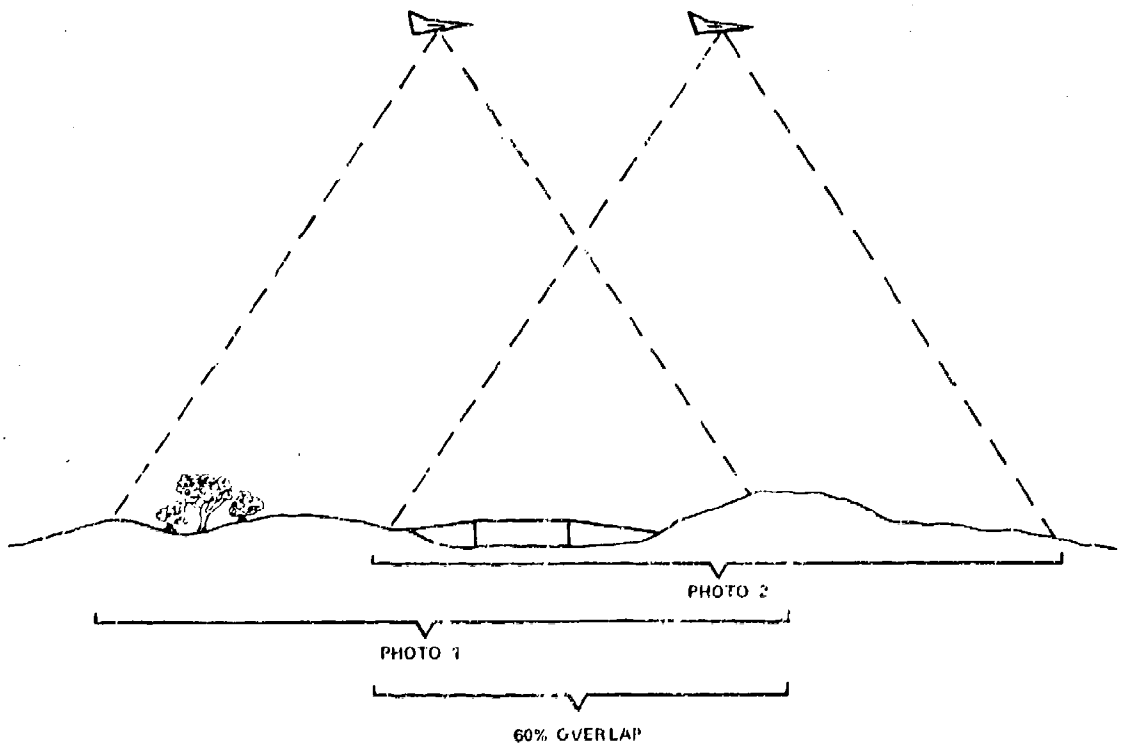
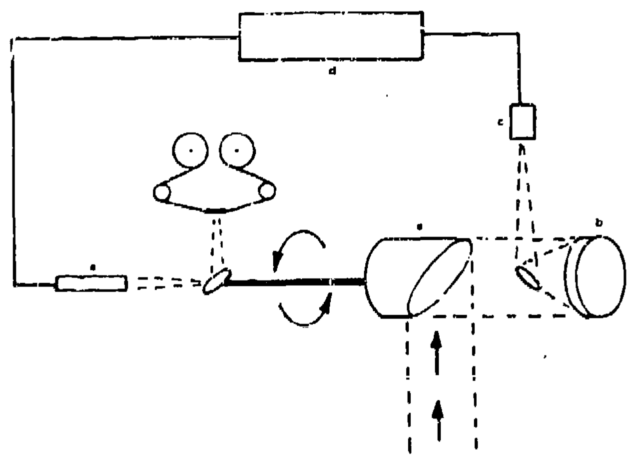


Figure 3-12 Stereo Imagery Generation

region over which maximum radiant energy or power occurs is a function of the absolute temperature and the emissivity of the object.

At earth ambient temperatures of 300°K (27°C), peak radiant intensity occurs at a wavelength of about 10 microns. For warm and hot objects, the peak shifts progressively to shorter wavelengths. Only when the object is incandescent does a sufficiently large fraction of the total energy emitted occur at wavelengths short enough to be visible to the eye. Passive IR devices are designed to sense in the so-called "thermal IR" region (2.5 to 14 microns) where objects at temperatures from 200°K to over 1000°K radiate with sufficient intensity to be sensed by one or more of a family of IR detectors. The atmosphere is highly transparent at specific wavelength intervals over this span, with the "windows" at 3 to 5 and 8 to 14 microns of greatest interest for surveillance and target acquisition.

Optical-mechanical line-scanning techniques are widely used to record thermal imagery. Basically, an IR detector element is fixed in the instrument while Field of View (FOV) is passed before it systematically through the use of a rotating or oscillating mirror (Figure 3-13). The detector thus scans the object plane. The detector output, varying with incremental differences in scene temperature and emissivity, is an electrical signal which can be displayed in real time, or can be recorded on tape or film for future examination. An IR image of the scene is formed from the detector signals by synchronizing the display scan with the optical-mechanical scanner (Reference 25).



THIS ILLUSTRATION SHOWS THE ESSENTIAL FEATURES OF SCANNING SYSTEMS. RADIATION STRIKES THE SURFACE OF A ROTATING MIRROR (a), AND IS REFLECTED TO THE SURFACE OF A PARABOLIC MIRROR (b), AND THEN TO A SOLID-STATE DETECTOR (c). THE OUTPUT OF THE DETECTOR IS AMPLIFIED (d), AND MODULATES THE OUTPUT OF A LIGHT SOURCE (e). THE MODULATED LIGHT IS RECORDED ON FILM (f).

Figure 3-13 Typical Infrared Scanning System

Airborne surveillance systems employ a unidirectional scanner which sweeps a path below and normal to the direction of flight. The second dimension (that of the flight direction) is provided by the motion of the aircraft, as shown in Figure 3-14, so that the imagery produced is in continuous strip form. The ground pattern coverage shown in Figure 3-11 for aerial photography also applies for IR systems.

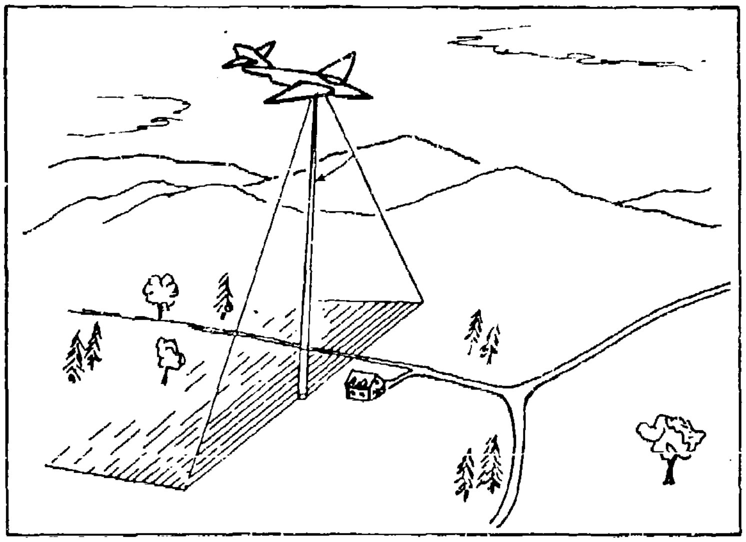


Figure 3-14 Line Scanner Ground Coverage

Imagery is also produced by two-dimensional or "raster" scanning. In this case, the image is time framed in a form similar to conventional television. Raster scanning systems for use aboard aircraft, ships, or vehicles have come to be known as downward- for forward-looking infrared systems (DLIR or FLIR), while the unidirectional line scanner is simply called a line scanner. Both line scanners and DLIR's/FLIR's of today employ many detectors to effect greater scanning speeds.

Characteristics of passive IR line scanners most significant to target acquisition and surveillance applications from ground, air, and space platforms are:

1. Total FOV or width of scan sweep in degrees.

2. Incremental FOV or angular resolution in milliradians.

3. Noise equivalent differential temperature (NEΔT); the effective temperature difference between adjacent resolution elements which produces a signal equal to the noise in the system. This is related to thermal resolution, which is the difference in temperature of two adjacent resolution elements of the same emissivity which can just be resolved in the imagery.

4. V/H, the ratio of maximum aircraft speed to height above the ground, in radians sec^{-1}, for which contigous scan lines can be produced.

These four principal system parameters incorporate all of the design features of the line scanner, including detector sensitivity in the spectral region of interest, detector response time or scanning rate, diameter of the entrance aperture and transmission of the optics, and electronic bandwidth and internal noise in the system. The display seldom places a limitation on detection but does limit recognition and identification. Reference 14 contains a discussion of these limitations. The four parameters are interdependent and, therefore, all cannot be optimized simultaneously in one system. Consequently, line scanners are designed to optimize those parameters which are of paramount interest for a given application at the sacrifice of less important parameters.

Range of line scanners can be determined from analytical expressions involving, at least indirectly, the parameters discussed. A range equation for detection by an IR sensor which calls out the essential consideration is:

$$R = \left(J\tau_a\right)^{1/2} A_o \left(\frac{\tau_o}{f}\right)^{1/2} \left(D^*\right)^{1/2} \left[\frac{1}{\omega\Delta f^{1/2} \left(\frac{V_s}{V_n}\right)}\right]^{1/2}$$

where

R = range

J = radiant intensity of the target over the background $W(sr)^{-1}$

τ_a = transmission of the atmosphere

A_o = area of the entrance optics

f = equivalent focal length of the optics

τ_o = transmission of the optics

D^* = detectivity of the IR detector at the spectral range of interest

ω = instantaneous FOV of detector, or angular resolution

Δf = bandwidth of electronic system

V_s/V_n = signal to noise ratio of the system necessary for desired probability of deduction

This expression shows that range is highly dependent on the thermal characteristics of the target, and on atmospheric conditions. D* should be maximized, but theory indicates a limiting value dependent on wavelength of operation and the radiating properties of the background on which the target is superimposed. The instantaneous FOV is related to detector dimensions, as well as the optics; reduction of detector size has technological limitations and the optical system has light diffraction limitations, both of which place a lower limit on angular resolution. High resolution combined with a large total FOV produces high information rates which require wide-bandwidth signal processing electronics. The large Δf tends to nullify range increases brought about by reducing the FOV. Scaling up the IR scanner system dimensionally will increase range, but necessary design tradeoffs are such that the weight of the system increases approximately as R^6.

The IR detector, the transducer of IR radiation to an electrical signal, has played a major role in the development of IR scanners to their present level of importance. IR detector development was given impetus at the end of World War II through knowledge gained from German technology. More recent improvements have been in detector sensitivity, spectral extension to longer wavelengths in the IR, shorter detector response time, and the ability to make close-spaced linear and two dimensional arrays of very small detector elements.

Detectors used in the IR line scanners developed shortly after World War II and continuing to the late 1950's were the thermistor and members of the lead-salt family of materials, notably the lead sulfide (PbS) detector. The thermistor is not highly sensitive, is slow in response, but is uniformly sensitive throughout the IR spectrum. It still is in use for short-range applications where dwell times on the target can be on the order of seconds. The PbS detector was the only fast detector in use until about 1957. Cooling this detector with dry ice or liquid nitrogen increased its sensitivity. Airborne scanning systems based on this detector were suitable for detecting warm targets because of the cutoff of sensitivity in the far-IR region where detection of targets with near-earth-ambient temperatures is most effective.

Introduced in the late 1950's, the lead selenide (PbSe) and indium antimonide (InSb) detectors, sensitive in the 3- to 5-micron atmospheric window,

made airborne mapping and reconnaissance feasible by resolving temperature differences as small as a few degrees Celsius. The detectors are cooled during operation. Both are in use today for many applications, but in line scanning and FLIR technology they are giving way to fast detectors sensitive in the 8- to 14-micron atmospheric window, considered now to be the most effective of the atmospheric windows for conducting ground surveillance and target acquisition. Atmospheric attenuation precludes operation at wavelengths larger than 14 microns.

In 1960, the mercury-doped germanium (Ge:Hg) detector made its appearance as a highly sensitive, fast detector for the 8- to 14-micron wavelength region. It requires cooling to 28°K with liquid helium or a closed-cycle mechanical refrigerator. In part, because of the cooling requirement, this detector has now been superseded by the mercury-cadmium-telluride (HgCdTe) detector which exhibits comparable performance with cooling to only 90°K, attainable through the use of the liquid nitrogen or argon pressurized in small flasks. The lead-tin-telluride (PbSnTe) detector may eventually replace the HgCdTe detector since it appears to offer the same performance at lower cost, especially for multi-element arrays.

In contrast to NEΔT, high resolution is a goal for most applications since it is a governing parameter in extension of range. NEΔT is inversely related to angular resolution, therefore, attainment of high resolution in FLIR and DLIR systems generally requires a relaxation of NEΔT performance. Angular resolution is limited fundamentally by diffraction phenomena in the optical system and also by normal atmospheric turbulence. Resolution can be improved by increasing the diameter of the entrace aperture of the system but practical sizes (12-to 15-cm diameter) tend to place a lower limit on resolution for sensing in the 8- to 14-micron region.

3.5.5 Laser Systems

Advancements in laser technology over the past decades have resulted in increased applications of laser systems in tactical roles. Brief descriptions of low-energy laser applications in the areas of target designators, rangefinders, multispectral scanners, and Doppler lidar (the optical counterpart to radar) are presented herein. Characteristics of tactical laser systems are given in Reference 26. The actual selection of laser wavelength(s) for a particular application is determined by a combination of the state-of-the-art of sensor technology, the propagation characteristics (through the atmosphere), and the nature of the interaction between the target and its surroundings.

Laser target designators (LTD's) have been employed successfully to guide bombs, missiles, and projectiles to a target illuminated by the laser. The designator laser must be in the line-of-sight to the target and the laser beam must be reflected from the target with sufficient intensity and for a sufficient time to permit the homing device to acquire the target, lock-on, and be guided to it. To the seeker, the target (by definition) appears to be the source of radiation. It is desirable for the target of interest to act as a diffuser rather than specular reflector of laser

radiation so that both the illumination and acquisition of the target are not dependent on direction so long as the laser source and the seeker are in the same hemisphere. In the wavelength from 1 to 4 microns, the reflectance of most targets is largely diffuse.

The important parameters of the LTD/seeker system which permit target acquisition and lock-on are the detector's sensitivity and radiant power level at the seeker. It is important that lock-on occurs at sufficient distance from the target to permit the guidance-and-control system to correct the flight path of the projectile, bomb, or missile in order to hit the target. The range will depend upon such factors as the characteristics of the laser source, the seeker, the target, and the prevailing weather conditions. The factors associated with the target include: target reflectance coefficients, which specify the geometry and magnitude of diffuse scattering; the effective target area relative to beam cross section area; and, of less importance, laser-beam polarization. Alteration of these factors affects target acquisition. The natural background reflectance characteristics can also affect acquisition in the case of laser-beam spillover.

A laser commonly used as a target designator is the neodymium doped yttrium aluminum garnet (Nd:YAG), operating at a wavelength of 1.06 microns which is within a good atmospheric transmission window. Such a laser system can be deployed on aircraft or used on the ground to designate armored vehicles, etc. The CO_2 gas laser, operating at a wavelength of 10.6 microns, can also be used as a designator. The TEA (transversely excited atmospheric pressure) CO_2 laser can be pulsed at rates exceeding 1000 pulses/second and has a higher energy output capability than the Nd:YAG laser. The reflected CO_2 beam from armored vehicles such as tanks, however, is predominantly specular and can affect the probability of the seeker acquiring the target. The ruby laser, operating at a visible wavelength of 0.694 micron, has been used in a target-designator role in Southeast Asia. Because of the visibility of the beam, this laser has been found to be less effective than covert lasers operating in the IR spectrum.

3.5.6 Laser Rangefinders

The laser rangefinder finds application in ground combat situations primarily as an adjunct to conventional firepower. Such devices are especially useful when deployed on standard tactical systems such as tanks.

The laser rangefinder comprises a pulsed laser and a collocated receiver. The rangefinder is able to determine distance electronically by comparing the time relationship of emitted pulses with received pulses. This is a line-of-sight system where the detectable radiation is reflected back along the incident beam path. As in the case of the laser designators, target size, target reflectance characteristics, as well as atmospheric conditions will determine the reflected beam intensity at the rangefinder receiver. Lasers which can be used as rangefinders include ruby (0.694 micron), Nd:YAG (1.06 microns), and CO_2 (10.6 microns).

3.5.7 Laser Scanners/Multispectral Target Enhancement

Multispectral line-scan laser systems concurrently utilizing various types of lasers such as argon, krypton, Nd:YAG, and CO_2 operating in the visible and IR spectrums have been used to illuminate on-the-ground objects, thereby providing a composite image composed of variations of the spectral reflectances of such objects relative to the background. The laser beams scan the FOV in raster fashion with optional modes of electronic signal processing, including on-board aircraft systems and/or ground-based computer analyses of satellite signal transmissions. Signal processing can be systematically employed to identify specific ground target signatures. The narrow laser beam width and the speed of the scan make it almost completely undetectable, either by eye (for argon and krypton lasers) or by IR warning receivers (for Nd:YAG and CO_2 lasers).

The laser has been shown to be feasible for target cueing within the scene displayed by a FLIR thermal imaging system. The wavelength of the CO_2 laser, 10.6 microns, is compatible with the spectral band, 8-14 microns, employed by FLIR systems. In the case of man-made targets usually of interest, reflectance tends to be predominantly specular at 10.6 microns as compared to natural backgrounds. Therefore, man-made targets are highlighted by the laser beam and direct the viewer's attention to that part of the scene where the highlight occurs. The CO_2 laser also has shown promise as a general scene illuminator for the FLIR for inspection of all details.

The range and image quality of the multispectral laser scanners depend on reflectance differences between targets and naturally occurring objects. The reflection contrasts can change during the day with atmospheric conditions (rain, snow, dust, etc.), target activity (warm surface melting the snow or ice, for example), and with seasonal and scenario changes.

3.5.8 Laser Doppler Lidar

Lidar systems utilizing a continuous-wave coherent laser transmitter (such as a CO_2 laser), an optical scanner, and optical heterodyne receivers have been successfully demonstrated to have the ability to detect objects with a motion component along the laser beam. Capability of detection, and discrimination of slowly moving personnel obscured visually by foliage, has been demonstrated even in the presence of significant wind activity. Such laser systems can be used in conjunction with laser rangefinders to provide targeting information for conventional firepower.

3.5.9 Microwave Systems

Microwave sensors may be divided into three broad categories: electronic intelligence, radiometric, and radar. Electronic intelligence sensors detect the presence of intentional or spurious emissions from transmitters, ignition systems, other electronic radiators or chemical combustion.

Radar systems are of more interest than radiometric systems which sense temperature contrast with the background. Metallic targets reflect the cold temperatures of the sky, while the surrounding land and vegetation appear warmer. Passive radiometers are bistatic radar systems. Active radiometric systems are radars which transmit noise signals. The larger the radar cross section, the more signal is reflected, and the hotter the temperature appears. Targets must have a reflectivity different from that of the background for the radiometer to see the contrast. Any method of controlling the radar cross section will thus control radiometric reflections, either active or passive.

Radar systems have been used extensively by the military since World War II and for monitoring ionospheric conditions since the mid-1920's. A radar system comprises a transmitting system which generates a propagating electromagnetic signal and a receiving system which analyzes the signal reflected off the target. There are many types of radar systems. They may be monostatic (receiving and transmitting systems collocated), bistatic or polystatic (several separated receiving systems for one transmitting system). They vary in range from radar fuzes with a range of a few centimeters to radar astronomy systems receiving signals reflected from other planets. They vary in complexity from simple intrusion detectors to highly sophisticated phased-array systems receiving signals from many rapidly moving, similar targets and discriminating among them. Incompatibilities in missions may prevent implementations of improvements obtained for one type of radar system on other types; however, it is necessary to examine the entire field of radar systems in order to project the future system developments of interest to Army countersurveillance planning and decision-making. Military radars include man-pack, transportable, battlefield surveillance, mortar locating, aircraft and missile detection and tracking, fuzes, missile guidance, terminal homing, reconnaissance, and surveillance.

The important parameters of military radar systems are their frequency, range, and resolution. Table 3-4 is a listing of the principal frequency bands.

The classified Annex to this Guide contains performance data on some of the Soviet radar systems. The data includes range and frequency information for Air-to-Ground, Battlefield Surveillance, Countermortar/Counterbattery, and AAA Fire Control Radars.

The range is a design parameter and can be set at any distance, but a microwave radar is basically limited by the line of sight. The line of sight depends upon the height of the radar antenna and the height of the target. Extending the range can only be accomplished by: elevating the radar; use of over-the-horizon radar operating in the high frequency (HF) band; or by taking advantage, when possible, of non-normal propagation conditions such as ducting.

Radar systems are principally distance-sensitive devices while photographic systems are principally angle-sensitive devices. This means that airborne radar imagery is most meaningful at great distances from the aircraft where

photographic imagery is least informative, and radar imagery is least informative directly below the aircraft where photographic imagery is more informative. Airborne surveillance radars are, therefore, usually mounted in the side-looking configuration of Figure 3-11 which creates a dead zone directly beneath the aircraft.

Table 3-4

RADAR BAND DESIGNATIONS

Band	Frequency, MHz	Wavelength, Cm
A	0-250	120-
B	250-500	60-120
C	500-1,000	30-60
D	1,000-2,000	15-30
E	2,000-3,000	10-15
F	3,000-4,000	7.5-10
G	4,000-6,000	5.0-7.5
H	6,000-8,000	3.75-5.0
I	8,000-10,000	3.0-3.75
J	10,000-20,000	1.5-3.0
K	20,000-40,000	0.75-1.5
L	40,000-60,000	0.5-0.75
M	60,000-100,000	0.3-0.5
	FORMER BAND DESIGNATIONS	
P	300-1,000	30-100
L	1,000-2,000	15-30
S	2,000-4,000	7.5-15
C	4,000-8,000	3.75-7.5
X	8,000-12,500	2.4-3.75
K_u	12,500-18,000	1.67-2.4
K	18,000-26,500	1.0-1.67
K_a	26,500-40,000	0.75-1.0

In radar, two types of resolution are important: range and azimuth. Range resolution is largely determined by the pulse length chosen. Range resolution and range accuracy of battlefield surveillance radar, particularly those using pulse compression techniques, are quite high and further improvement is not necessary for most applications.

High angular resolution is a desirable property for a radar system. The angular resolution of World War II radars was limited by the physical size of the antenna. There is a definite relationship between the size of an antenna measured in wavelengths and its directivity. Since at that time an increase in directivity was the only way to obtain an increase in angular

resolution, the only ways to improve resolution were to use larger antennas or to operate at shorter wavelengths. This situation is still true for man-pack radars. Since there is a limit to the physical size of the antenna that can be man-packed, and since frequencies higher than J/K-band are severely affected by weather conditions, the angular resolution of man-pack radars has remained constant with time at about 10 milliradians.

Since World War II, two signal-processing techniques have been devised to increase performance. One is termed "monopulse" and involves the use of two separate antenna feeds, and the sums and differences of the signals from these feeds. By proper manipulation of the signals and antenna positions, a null is pointed toward the target on the difference channel. This null can have one-tenth the beamwidth of the original antenna pattern and thus increase the directivity. This technique is primarily implemented against air targets where the background does not produce much clutter.

A second technique is the synthetic aperture principle. The physical antenna aperture is moved and the signal added coherently over a period of time. This technique has improved the resolution of airborne radars by as much as two orders of magnitude. Against moving targets, a cross-over time can be computed which indicates the maximum time that a signal may be integrated without the motion of the target degrading the integration. The resolution of synthetic aperture radars (SAR's) is primarily limited by the memories of the associated computer systems. Figure 3-15 illustrates the angular resolution (meters per kilometer range) for representative U. S. synthetic aperture radars (Reference 15).

Since World War II, much effort has gone into the features of radars which might be explored for cueing man-made targets. Extensive efforts have gone into polarization and cross-polarization studies, target fluctuation studies, and target angular sensitivities. Even more work has gone into moving target indicators (MTI's) and Doppler modes of detecting both high-value targets and individual soldiers on the basis of their motion.

One form of the radar range equation is:

$$R^4 = P\ A^2\ \sigma/(4\pi\lambda^2 S)$$

where R is the range at which the receiver power is equal to the receiver minimum detectable signal S. A is the antenna effective aperture area, P is the transmitted power, λ is the wavelength of the radar energy, and σ is the radar cross section of the target. This equation is useful for rough computation of range performance, but is simplified and gives overly optimistic values.

When the target is located in a background which reflects radar energy, these unwanted clutter echoes can severely limit the detectability of the target. When clutter power dominates receiver noise power, the range equation reduces to an expression for signal-to-clutter ratio.

$$R = 2\sigma/\left\{\sigma^0 \theta c\tau \sec(\phi)\right\}\ (S/C),$$

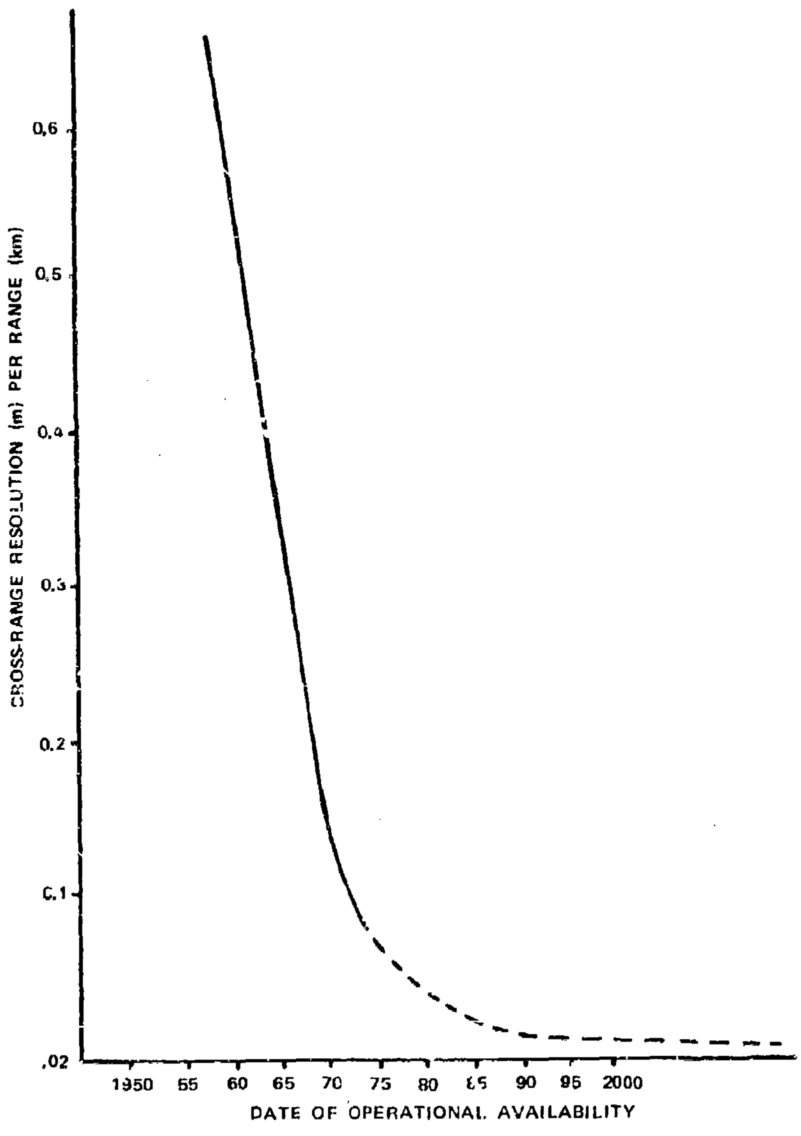


Figure 3-15 Trend and Forecast for Synthetic-Aperture Radar

where R is the range to a clutter patch, σ^0 is the normalized clutter coefficient, θ is the azimuth beamwidth, c is the velocity of propagation, τ is the pulse width, ϕ is the grazing angle, and (S/C) is the signal-to-clutter ratio of the receiver. The detection range is thus seen to be dependent on the ratio of the target cross section to the clutter cross section of the background - and not just on the target cross section alone.

There are a number of microwave systems under development which take advantage of the fact that metallic targets resonate at frequencies different from those of an exciting energy source, and thereby enable positive identification of metal targets. Although it is not known whether similar systems are being investigated in the U.S.S.R., the reader should be aware of two such U.S. developments because of their possible potential for close-in target detection, either by themselves or in conjunction with more conventional radar. These new sensing systems are called the METal Re-radiation RAdar (METRRA) and the RAdar Detection of Agitated Metals (RADAM) concepts.

The METRRA is claimed to be the only all weather sensor capable of sensing and detecting a complctely stationary and quiescent metal target through foliage. It operates by exciting metallic objects in the field of view at frequencies of around 220 to 450 MHz, and then detecting any resulting third harmonic energy or other frequencies created by the non-linear electrical contacts inherent in man-assembled equipment, but not present in nature. Present disadvantages of the METRRA systems are a somewhat minimal detection range (approximately 1 kilometer for 100 kilowatts) and a very low resolution. However, it definitely has a capability of detecting a target in natural clutter by statistical comparison techniques.

RADAM is also a metal-detecting radar which can operate from the UHF through the X-band frequencies and detect, locate, and (possibly) identify moving or agitated metal targets (e.g., armored personnel carriers) through foliage. It operates by detecting any abrupt switching in the RF current which might be created by vibrations or mechanical separation of moving elements such as gears, rotors, etc. Present disadvantages are poor resolution and range, along with a tendency to be confused by normal Doppler returns at other frequency ranges.

3.5.10 Unconventional Sensors

Unconventional sensors are those that generally utilize one or more signatures that are totally different, either in type or spectral region, from the more conventional sensors. Their mission is usually: (1) to determine the location and/or movement of enemy personnel and motorized vehicles, or (2) to establish the coordinates of hostile indirect-fire weapons. In most instances, this detection of personnel and motorized vehicles utilizes a network of unattended ground sensors (UGS) to acquire data on the general location, direction, and concentration of the enemy's infiltration efforts. Quite often this information is included in the intelligence category and immediate action is not required or even desirable. Air and artillery strikes, however, have been based directly on UGS information with some degree of success.

Each UGS unit contains an antenna and transmitter so that the detection of intrusions can be communicated to the appropriate receiver. If a number of sensors are involved, then a centralized computer facility is employed. The computer processes the data and displays it in a format that can be interpreted by trained personnel. The telemetry link from the sensor may be direct, but normally an elevated relay such as a tower on a hill, a balloon, or an orbiting aircraft is involved. The sensors are emplaced on or in the ground, or in the case of dense jungle canopy, may be hung in the upper branches of trees. Both hand and air-drop emplacement have been used extensively.

The second category of unconventional sensors, those to be used to determine hostile indirect-fire weapon coordinates, have a number of similarities with the first. They are normally employed as an UGS net with the data telemetered to a centralized computer processer. Emplacement is in or on the ground. The major difference between the two categories is the requirement for relatively high accuracy for location of the enemy and the need for real to near real-time interpretation of the data. It is also to be noted that UGS networks for detecting personnel and motorized vehicles operated quite successfully in Southeast Asia.

3.5.11 Personnel and Vehicle Detection

A wide range of sensing techniques has been utilized in the development of UGS's. In particular, the following types of sensors have been fabricated:

- Acoustic - Passive detection of sound generated by personnel or vehicles. Have been used in conjunction with button bomblets.
- Seismic - Detection of microseismic disturbances created by passage of man-made activity.
- Magnetic - Detection of changes in the local geomagnetic field as a result of the motion of ferromagnetic material in the vicinity of the sensor.
- Electromagnetic - There are two types: active, which generates a low power RF signal; intrusion causes a shift in the frequency. Passive, which detects the RF noise emitted by a "noiseless" button bomblet.
- Infrared - There are two types: active, which includes an IR source and IR sensor; interruption of IR beam generates alarm message. Passive, which detects difference between IR radiation of intruder and background. Both the active and passive can be designed to determine direction of intruder's motion.

- Pressure - Detection of pressure change due to direct contact or extremely close intrusion.

- Strain - Detection of soil mechanical strain caused by intrusion at very close range.

Low signal-to-noise ratio and high false alarm rate (FAR) represent two of the major UGS problem areas. A number of techniques have been tried in order to improve performance. Quite often a sensor's threshhold is adjusted to the immediate background noise level via a type of automatic gain control. Correlation techniques and self-contained logical algorithms have been used to increase sensitivity and reduce the FAR. For example, it has been found that the acoustic output of motorized vehicles contains distinct line emissions in some parts of the spectrum which are usually a function of vehicle type. This information has been used successfully for discrimination purposes. Criteria such as signal rise time above a given rate and the number of times this occurs within a specified length of time have been incorporated into some sensor logic circuits. Combination of two sensors has become popular technique. In many instances, a seismic detector is used to cue another type of sensor.

A list of sensors is described in some detail in Reference 27. Some of the sensors were designed only for counter-intrusion along the perimeter of various facilities such as a missile silo.

Another class of UGS sensor employs chemical detection to detect the presence and type of vehicle by analyzing the engine exhaust emissions. The work is preliminary but promising. A variety of other sensor concepts have already been investigated, including: condensation nuclei, ionization, surface adsorption, chemiluminenscence, flame photometry, thermal conductivity, mass spectrometry, plasma chromatography and others.

3.5.12 Hostile Indirect-Fire Weapons Location

For this application, a network of sensors is employed to determine the coordinates of enemy indirect-fire weapons such as field artillery, mortars, and rockets. The timeliness and accuracy of the information should be adequate for directing effective counterfire. The types of sensors that have been given the greatest emphasis are acoustic, seismic, flash, and electromagnetic. These are all passive detectors of the events associated with the burning of propellant.

Fifteen percent of the enemy's artillery positions located in World War II were located through visual flash detection. A typical system consists of azimuth measurements by two observers 2 kilometers apart with the target coordinates, determined by triangulation.

Modern flash detection systems detect the infrared portion of the weapon flash. The infrared region has definite advantages over the visual region because flash energy in the infrared has:

- Higher radiant intensity level
- Longer flash duration
- Better discrimination of background radiation
- Better atmospheric transmission

Reference 28 lists the detection range and accuracy possible with U.S. infrared flash detection systems.

Reference 29 describes the capabilities of a precision telescope system and many other gun flash sensors that have been developed and, in most cases, tested.

Reference 28 contains a discussion of the electromagnetic emission from weapons and explosions and estimates the detection ranges for weapons from cal. .30 to 8 inches. References 29 and 30 are volumes III and IV in a series on weapons locating systems. Volumes I and II in the same series deal with acoustic and seismic deception of hostile firing weapons.

3.6 SENSOR OPERATIONAL CONSIDERATIONS

3.6.1 Sensor Limitations

If only the technical resolving powers of remote sensing systems were to be considered in the environment most favorable to sensors, it would indeed be a grim world for those depending upon camouflage. All targets of interest would be seen and destroyed. And yet this has never happened because of many factors which continue to exist war after war.

There are many circumstances which limit the performance of remote sensing systems in field situations. In combat these circumstances multiply and magnify even more. It follows that camouflage is more successful in combat than in planned or nonstressful field tests. The limitations of remote sensor systems should be accounted for before countermeasure goals are established since camouflage needs only to be designed and employed to meet field and operational conditions.

3.6.2 Platform Constraints

Each sensor is associated with a platform which supports, positions, and directs the sensor. The soldier is the platform for the eye; the vehicle is the platform for the mobile radar, and a satellite is the platform for aerial cameras. The performance of the sensor is dependent upon the characteristics of the platform. The platform has to place the sensor within effective range of the target, and must position the sensor within the line of sight of the target. The field of view of the sensor might be

partially obstructed by an inappropriate choice of platform position. The platform location determines the direction from which the target is viewed (ground mounted sensors view only the side aspect of a target; aerial sensors view only the overhead aspect). The speed or vibration level of the platform must not be excessive or image blur will occur, and the platform must not be sensed by the sensor (acoustic sensors would not be effective if mounted on a noisy platform).

Not all sensors are mounted on all platforms. The classified Annex contains a combination matrix which shows the valid or probable combination of 28 sensing techniques and 7 platforms. Probable combinations are indicated by the symbol PC. Of 196 possible combinations, about 40% are probable and useful.

3.6.3 Environmental Characteristics

Environmental characteristics place limits on both the technical performance and operational employment of remote sensing systems. These considerations should be factored into any estimate of the extent of the threat posed by a remote sensing system.

The atmosphere is not uniformly transparent to all wavelengths of electromagnetic radiation; the spectrum has "window" areas (Figure 3-16) of relatively high transmittance in which remote sensors operate. These are the regions of the spectrum in which useable fractions of the energy from the target can be collected by the sensor. These windows are well known and limit the possible wavelengths of operation of some threat sensor systems.

The windows change with the state of the atmosphere. Increases in moisture content of the atmosphere will narrow the windows and reduce the maximum transmittance; rain will prohibit operation in some windows.

Terrain features are an obvious consideration for line-of-sight sensors, although certain radars have the ability to "see" through foliage.

Complexity of the background strongly affects the performance of the sensor operator. The detection of a single target against a uniform background that strongly contrasts with the target is a best-case situation which is not typical of the battlefield environment. But ground based radar detection of an aerial target is an example of such a situation. The ability of the sensor operator to distinguish between the target and the background degrades as the complexity (clutter) of the background increases. The visual complexity of open woodland is a familiar example. Complexity of the background is related to the density of non-target items in the sensor's field of view which appear similar to the target.

Sensor systems are sensitive to seasonal changes in the background. UV photographic systems, which exploit differences in reflection between white objects and snow, are ineffective when the background changes from winter snow to summer foliage. CD photographic systems, which exploit differences in reflection between green coatings and chlorophyll, are less effective in the

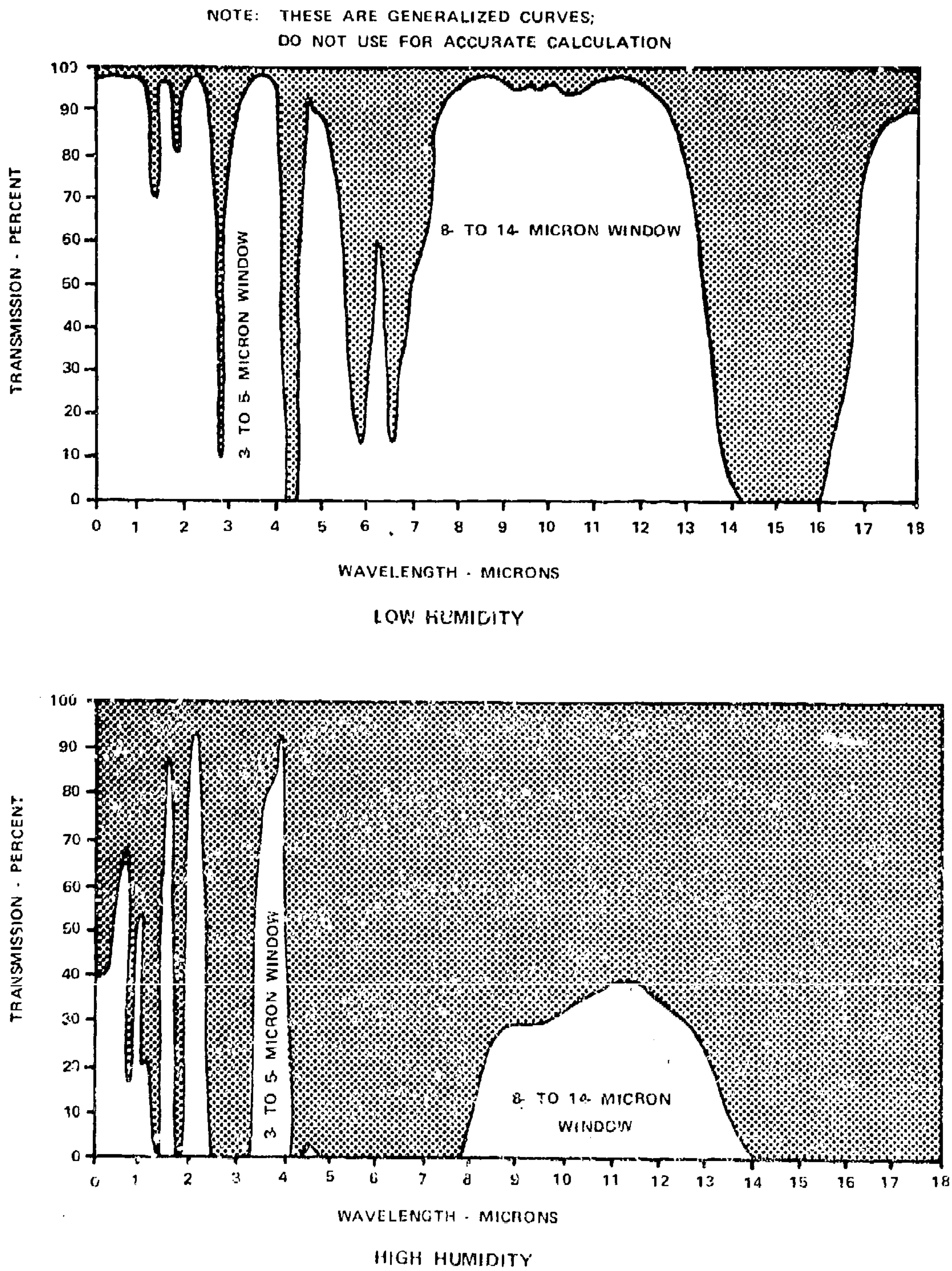


Figure 3-16 Atmospheric Infrared Transmittance at Sea Level

absense of foliage. Sun angle (or presence) will affect visibility range and shadow casting. Moonlight is a factor in night vision.

3.6.4 Remote Sensor-Item/System Encounter

The ability of a remote sensor to detect the presence of a friendly item/system is unimportant if such a detection opportunity is not going to occur. It may be tolerable if such detection is only going to occur rarely. Therefore, the probability of a sensor/target encounter which leads to detection needs to be calculated or estimated before a threat conclusion is reached. This step was shown as Level III in Figure 3-1.

The probability of an encounter between a target and a sensing system is dependent upon the availability, reliability, and the density of sensor coverage on the battlefield. Some areas of the battlefield are subjected to 24-hour surveillance; other areas have only occasional coverage. The expected number of item/systems (targets) on the battlefield, and their usage doctrine will affect encounter probability. Mobility and sensor effective range will affect encounter probability.

Sensor system availability is dependent upon the combination of natural events, design features, and employment doctrine. For example, covert aerial photography is limited to periods of low cloud cover, good visibility and daylight. The daylight restriction can be removed by a willingness to use artificial battlefield illumination sources. Some IR systems perform equally well in the day or night, but still are restricted by adverse weather conditions. Some radars come close to being true all-weather-day-night remote sensing systems. The mission time of some sensor systems such as UGS and satellites are power supply limited.

The density of coverage is dependent upon the number of systems available to the enemy and his employment doctrine for these systems. Human eyes are often the primary threat because of the sheer number available. Some sensor systems are so costly that the few available are restricted in their employment to the search for targets of extremely high value.

3.7 THREAT CONCLUSION

Once encounter probabilities which result in detection as a minimum have been determined to be of significant frequency (Level IV), the military significance of such encounters should be addressed. It is conceivable that some encounters are not significant. This begins to resemble war gaming when such questions arise as, "Now that detection has occurred, what is the enemy response, and therefore, what should be the friendly counter response?"

One determining aspect of this type exchange is the real time limitations that are involved between detection and action based upon detection. For imaging systems which are weapon sights, this time is the delay between

the gunner's detection of the target and his operation of the weapon trigger -- a few seconds at most. Aerial photography is the other extreme where there is a delay from several hours to days for return of the film from the plane or the satellite to the ground processor. The usefulness of remote sensing system data is a function of response time. Battlefield systems which change position within the response time of the sensor systems are little affected by the target location capability of the sensor system. Mobility and tactics are, therefore, factors in threat assessment.

Enemy doctrine and firepower are other factors. Does detection trigger firepower, and is the firepower likely to be effective?

An analysis of all factors, hostile remote sensors, item/system signature cues, tactics, doctrine, encounter probability, etc. will lead to a threat conclusion. The threat conclusion will identify the remote sensing system that is determined to be a threat, will define the conditions of range, platform, environmental and operational factors, and the time frame in which the threat is expected. Countering this threat as specified in the threat conclusion will become a camouflage objective.

3.8 REMOTE SENSING PROCESSES

In order for remote sensing systems to accomplish their mission, three processes must occur:

1. target detection by the sensing device
2. operator detection of the target as displayed by the sensing device*
3. correct operator interpretation of the detected target display*

These processes are illustrated in Figure 3-17. Assuming an optimum situation for the sensor (i.e., it is operating, the target is within its field of view, the target is emitting or reflecting signals within the sensor's design range, etc.), the sensor's ability to detect the target will depend upon cue signal strength relative to target background and sensor sensitivity. At this level of the remote sensing process, camouflage can prevent detection only by hiding the target or blending it into its background until the sensor cannot resolve the target's presence. As a practical solution, this is often not feasible, or at least not consistent with mission fulfillment.

The operator detection process must contend with either the fallibility of the human psychophysical and psychological system, or the inflexibility of pre-programmed logic, thus providing new degrees of freedom for camouflage countermeasures. The target may be detected by the sensor and presented in its output display without its presence being detected by the operator. This might be caused by the presence of background clutter, indistinct or

* In some systems, the operator (or human link) is replaced by programmed logic. Examples are radar fire control systems and missile homing systems.

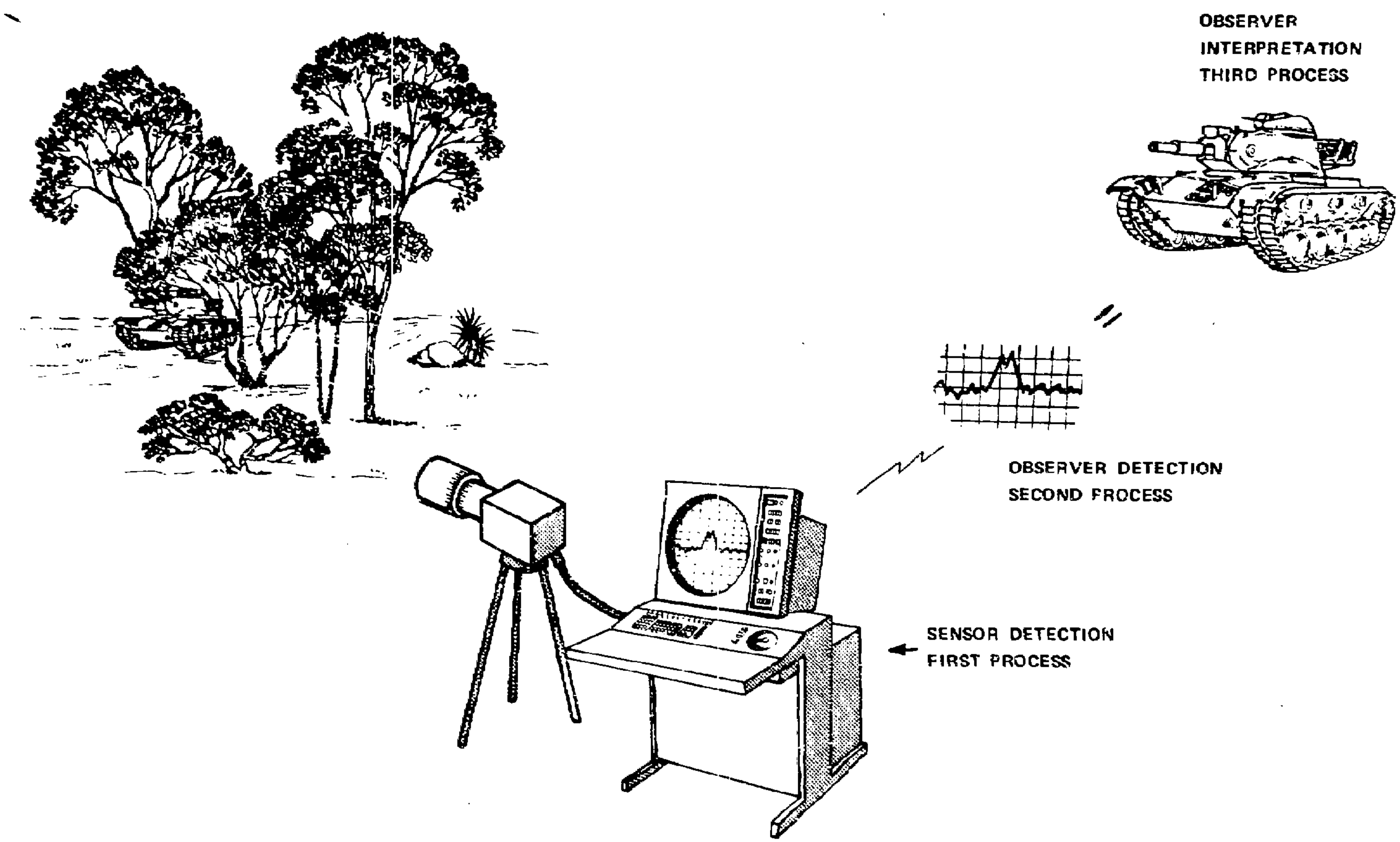


Figure 3-17 Remote Sensing Processes

confusing recognition cues, or operator variables such as fatigue, lack of motivation, lack of foreknowledge, etc. False alarms can be effective at this process level also.

The third process in the remote system sensing process requires some intelligence to decide whether the object displayed is of military interest. The human sensory system will, through analysis, ascribe some relationship or meaning to the pattern of information which is presented by the sensor. The deductive process will be used to sort out the available information in order to produce an interpretation that is consistent with the context and meaning of the total situation.

Tactical cover and deception practices are effective in creating erroneous interpretations of observed objects and activity. Masking attacks with maneuvers is an example. Camouflage can also affect this process by altering operational signatures or by downgrading the appearance of equipment. A missile battery might be made to appear as miscellaneous equipment by hiding selected items, or by arranging it in a non-conventional pattern. Similarly, tanks could be caused to be interpreted as trucks under some conditions of observation.

Each of the three processes should be considered for each expected specific item/system and remote sensing system encounter before selecting the countermeasure approach. It is also noted that combinations of hostile remote sensing systems may be encountered. Sensor interactions may be particularly relevant in the enemy's construction of his total intelligence picture, i.e., one sensor may detect presence, but not provide recognition until coupled with input from a second sensor. This aspect of the problem is mentioned here because in accordance with "the weak link theory," an analysis of the composite remote sensing system scenario may indicate a sensor and process link whose defeat would produce a disproportionately large countermeasure payoff.

3.9 EXAMPLE PROBLEM

An example illustrating the material discussed in this section is presented in Appendix A of this Guide.

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SECTION 4

COUNTERMEASURE GOALS

4.1 OVERVIEW

A completed threat assessment will indicate which hostile surveillance threats are of primary concern, and the general nature of what kind of camouflage is required to defeat the identified threat. For example, infrared camouflage is required to defeat FLIR sensors, visual camouflage is required to defeat black and white aerial photography, and radar camouflage is required to defeat SLAR systems. Still unanswered, however, are the questions of how much camouflage is needed, what are suitable design goals for camouflage, how is camouflage performance measured, what is the military worth of a specific camouflage treatment, and how is its worth judged?

Many people recognize that camouflage has military worth; measuring that worth is difficult and specifying how that worth is related to some measure of technical performance is a tough problem.

The mere existence of a hostile surveillance threat does not necessarily mean that a maximum effort should be directed toward making the friendly item/system undetectable by that threat. The cost and performance of a camouflage treatment should be balanced against the effect of the camouflage on expected military operations in a manner to optimize the utilization of the resources available to the U.S. Army. The primary aids to the decision maker faced with this task are the Military Worth Analysis and the Concepts and Analysis Study. The process of arriving at a countermeasure goal that is responsive to a particular threat assessment is presented in Figure 4-1.

While the developer remains responsible for the determination of the countermeasure goal for his item/system, one mission of the Camouflage Laboratory is to assist in this effort. This assistance can range from minor consultation using MERADCOM in-house funding to a complete countermeasure goal determination utilizing customer funding.

The Military Worth Analysis assists in determining what effect proposed levels of camouflage will have on the operational effectiveness of a force which contains the camouflaged equipment. Operational effectiveness looks to end results, and it is the degree to which the ability of a force to perform its mission is improved or degraded by the addition of camouflage to an item/system in the force. The analysis is quantified by measures of effectiveness (MOE), but there is a large judgmental element involved that deals with intangibles such as leadership and morale. Typical MOE are loss exchange ratio, rate of advance, casualty rate, and ratio of blue/red survivors.

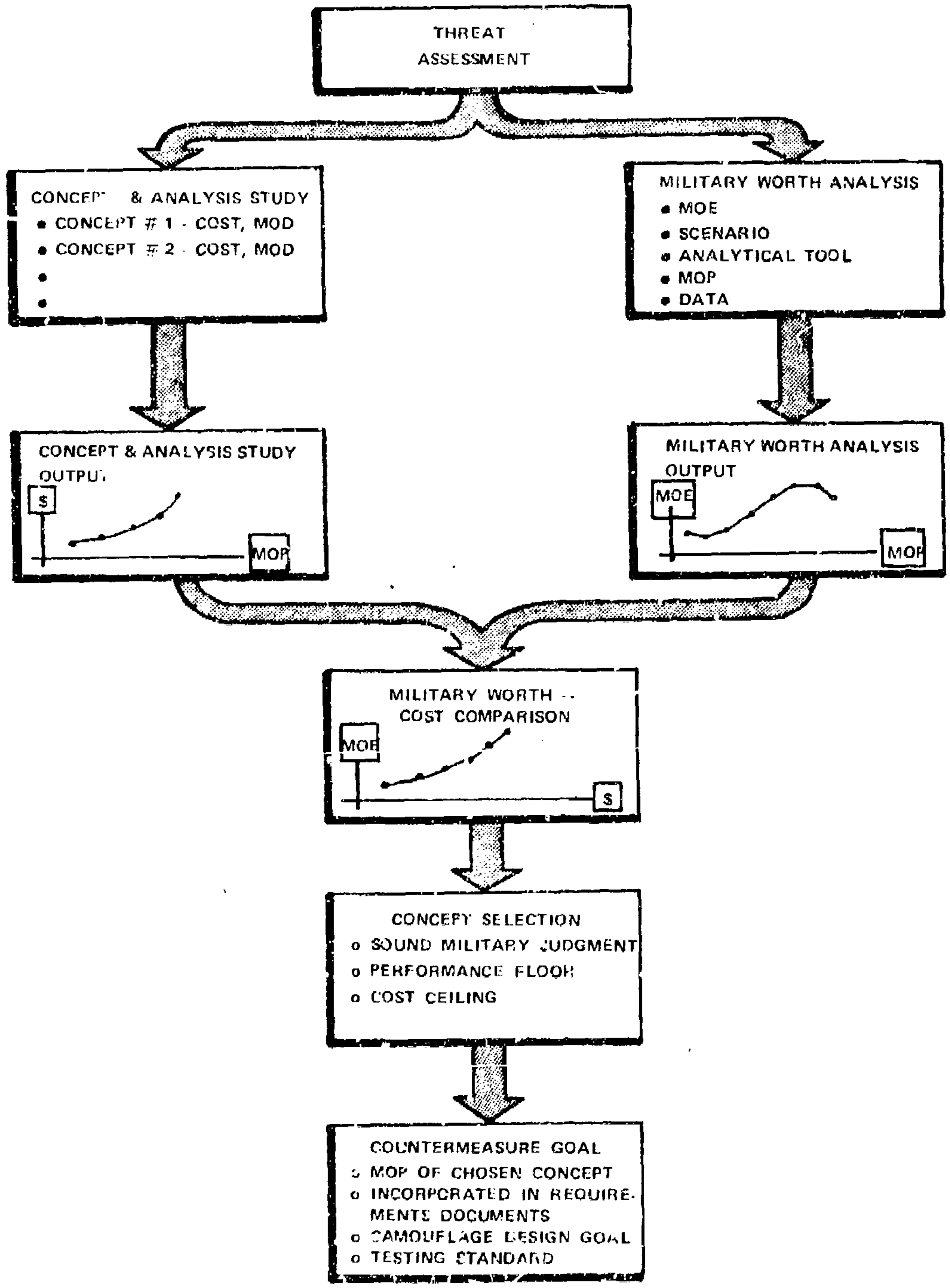

Figure 4-1 Countermeasure Goal Determination Process

Camouflage is accounted for in a Military Worth Analysis in terms of measures of performance (MOP). MOP are quantitative descriptions of the expected outcome of an encounter between the camouflaged item/system and the threat sensor and are not descriptions of the design of the camouflage. Typical MOP are: mean range to detection, time to detection, probability of detection, and location error to range ratio.

The result of a Military Worth Analysis is derived from a relationship between the measures of performance of various levels of camouflage and the measure of effectiveness of a force which includes one of the levels of camouflage. Such a relationship is indicated in Figure 4-2 where five levels of camouflage are considered. Level 1 may be considered the base case of no camouflage and Level 5 is a maximum camouflage treatment. The military worth of a camouflage Treatment is represented by the change in the measure of effectiveness from the base case. Reference 1, 2, and 3 are recent examples of Military Worth Analysis of Camouflage.

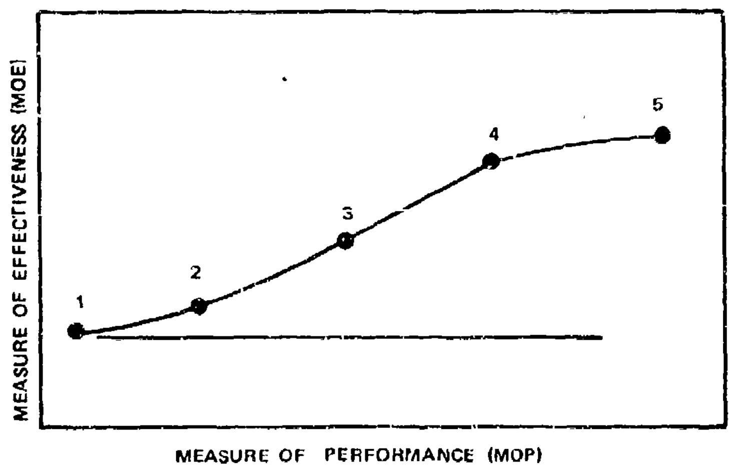

Figure 4-2 Example of Military Worth Analysis Results

A Concept and Analysis Study contains proposed camouflage treatments or designs which are expected to achieve a desired measure of performance and estimates of the cost associated with each concept. The results of this study may be as shown in Figure 4-3. Concept 1 does not have a cost associated with it since it is the uncamouflaged base case. The additional costs associated with the increased performance levels of the other camouflage concepts are indicated by the numbered points in the figure.

The combined results of the Military Worth Analysis and of the Concept and Analysis Study, as shown in Figure 4-4, furnish the decision maker sufficient information to decide which, if any, of the suggested concepts are

a cost effective camouflage solution to the threat. For each concept, there is available an estimate of the military worth and of the cost: Sound military judgment is required to determine which is the best combination.

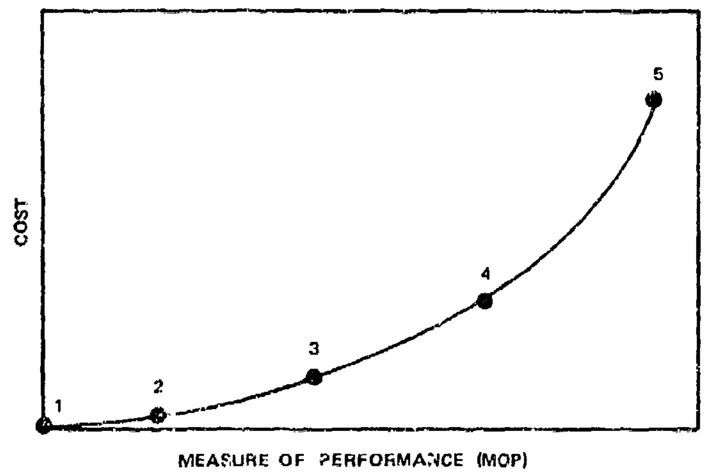

Figure 4-3 Example of Concept and Analysis Study Results

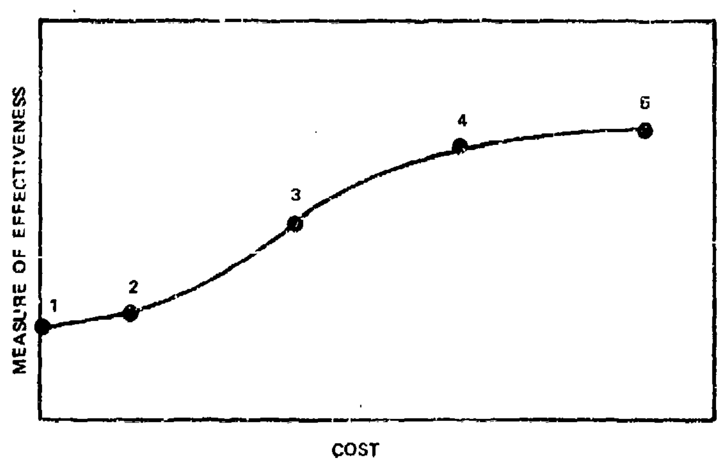

Figure 4-4 Example of Cost Effectiveness Analysis Results

For the example shown, the military worth of camouflage Treatment #2 may be considered inadequate even considering the low cost; and the increase in the military worth of Treatment #5 over Treatment #4 may not be worth the additional cost. Unless there are arbitrary cost ceilings to consider, Treatment #4 may be judged the most cost effective. If cost ceilings eliminate Treatment #4 from consideration, Treatment #3 would be the cost effective solution unless the military worth is shown to be only marginal.

It is not reasonable to expect that camouflage will be the only countermeasure considered, and a proper mix of countermeasures is sought which will produce the military worth for funds available and level of need. Reference 4 discusses cost effectiveness determinations.

The measure of performance associated with the camouflage concept selected as cost effective may become the countermeasure goal. This goal gives the developer definite criteria to work toward and provides an unambiguous standard for test comparison. This countermeasure goal has the desirable characteristics of being:

1. Stated objectively in performance terms and not as a description of signature characteristics such as radar cross section, reflectance, or luminance contrast.

2. Responsive to the threat by specifying a countermeasure to be designed for a specific threat sensor.

3. Specified to satisfy the level of need in terms of the Military Worth Analysis.

4. Achievable and realistic.

Example countermeasure goals might be to (i) reduce the mean range of detection of an item/system in a specific terrain by a specific sensor from 2,000 to 1,000 meters, or (ii) create a decoy object that will be misidentified as an item/system in a specific terrain by a specific sensor with a 90 percent probability at a range of 400 meters.

These countermeasure goals (statements of the performance expected or required of a camouflage treatment) are the most suitable form for stating camouflage requirements in a requirements document (OCO, LOA, ROC, LR).

4.2 MILITARY WORTH ANALYSIS

The five essential elements of a Military Worth Analysis are the measure of effectiveness (MOE), the scenario, the analytical tool, the measure of performance (MOP), and data. A MOE must be selected which can distinguish between alternative countermeasures to a specified threat. The scenario should be chosen to include the camouflaged item/system and the threat such that when used in games, models, or simulations, the selected MOE will be

produced. An analytical tool should be chosen that can exercise the scenario to produce values for the selected MOE. The MOP required by the analytical tool should be identified and the data, in terms of this MOP, required to exercise the analytical tool should be identified and obtained.

4.2.1 Measure of Effectiveness

An important consideration in selecting a measure of effectiveness (MOE) is the suitability of the MOE to the appropriate decision making level. There is a hierarchy of measures of effectiveness which is analogous to the level decision being addressed. In general, a MOE at one level is dependent upon one or more MOE at the next lower level. Figure 4-5 illustrates this hierarchy.

The ideal MOE for all systems would be Level I, the degree to which the camouflage improves the ability of the force to accomplish its mission. Unfortunately, in most cases, this MOE is not applicable since many alternatives to a system will accomplish the force mission, and the difference in degree of accomplishment by the various candidates may become difficult to distinguish. For studies involving the large forces of interest to the Department of the Army, Level I measures have more application.

Level II MOE best describe operational effectiveness in high resolution examinations, and are most suited for use in Military Worth Analysis. They measure end results, and measure those results in terms of the total force and not just the camouflaged item/systems under examination. Because they are end results and attempt to consider all the interactions on the integrated battlefield, they are few in number for a given analysis. The MOE most frequently used are: red casualties, blue casualties, ratio of red to blue casualties, rate of advance or withdrawal, time to accomplish a mission, and weight of munitions or other supplies expended. Although it is desirable to limit the number of MOE, sufficient MOE should be used to properly assess the camouflage.

Level III measures are performance characteristics. The characteristics shown in Figure 4-5 are key descriptors of camouflage performance. Performance characteristics usually represent performance against passive targets in one-on-one duels. They ordinarily are not suitable as MOE for operational questions because they do not describe the interaction between groups of weapons that occurs in an operation environment, but they are used as imputs into the Military Worth Analysis which will produce Level II MOE. Level III MOE are called measures of performance (MOP) in this Guide. Typical Level III MOE are shown in Figure 4-5.

Level IV MOE are of primary interest to technical people concerned with hardware development. These MOE contribute to the determination of performance factors, but they are rarely if ever suited for use as MOE or MOP in a Military Worth Analysis. Examples of Level IV MOE are shown in Figure 4-5.

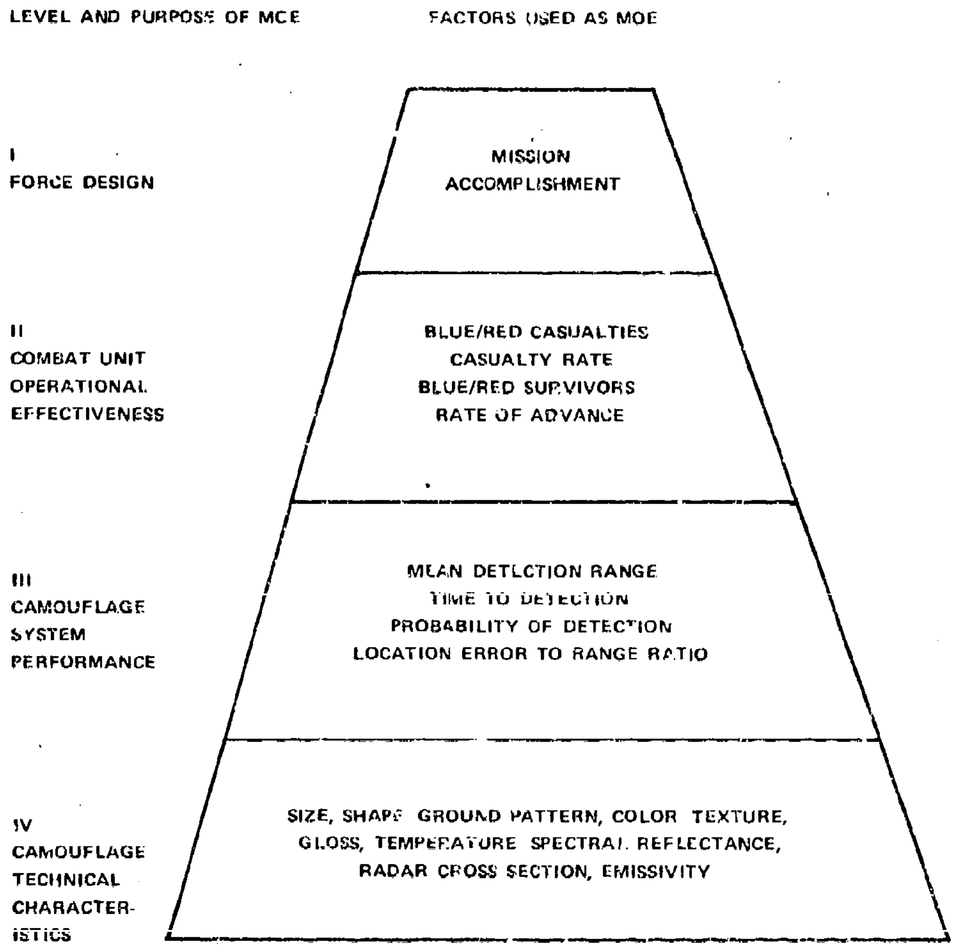

Figure 4-5 Measure of Effectiveness (MOE) Hierarchy

The Military Worth Analysis is the connecting link between Levels II and III in the sense that Level II MOE are the output and Level III MOP are the input. The relationship between the MOE and the MOP, shown graphically in Figure 4-2, is determined by the Military Worth Analysis.

4.2.2 Military Worth Analysis Input

4.2.2.1 Scenarios

Scenarios are selected to give a valid picture of the battlefield on which the systems being analyzed will play a significant role. They are a description of the blue and red force structure, troop disposition, equipment, tactics, missions, and of the weather and terrain. The scenario should create bias neither for nor against the camouflage. Both forces should be played objectively, their capabilities should be neither exaggerated nor minimized. The scenario should challenge the various camouflage concepts (Radar camouflage should not be played against FLIR's). The scenario should be designed so that it is possible to have a range of outcomes, thereby permitting comparison of alternatives (Camouflage should not be played against preplanned artillery strikes. See the discussion of the Sensitivity Analysis in Section 4.2.3).

4.2.2.2 Analytical Tools

The analytical tools (combat models) which exercise the scenario to produce the MOE are the most technical aspect of the Military Worth Analysis. There is a variety of analytical tools available to support a Military Worth Analysis. These tools are employed to reduce time and resources expended in the examination of a problem. Those tools which furnish the best data are most demanding in resources and time, as illustrated in Figure 4-6. All techniques can properly be called "models" because they parallel or "model" combat. All models are not computer simulations, although computer simulations have become the most widely used.

A model is a representation of the real world and produces numerical output which can be related to real world actions. Models supply information to the decision maker.

Models must be able to exercise the scenario selected and to produce MOE data. If a reconnaissance unit is being examined, the model must be able to play withdrawals, delaying actions, and the mobile defense. A model, designed to examine artillery systems (where the MOE is percentage of all targets killed by artillery), must be able to analyze lethality of the ammunition against such targets as moving tanks. MOE data must be produced by the model by logical methods based on sound military tactics. The model must demonstrate a cause and effect relationship understandable to the decision maker. This is often accomplished by a battle history which gives an event-by-event description of what occurred.

Characteristics of models, such as resolution, responsiveness, and realism are discussed in Section 6 of this Guide. Available combat models that are suitable for Military Worth Analyses are also discussed in Section 6

in terms of these characteristics. Reference 5 contains an analysis of available models and their application to camouflage analysis.

- Analytical Models

Analytical models (as shown at the top of Figure 4-6) can often be prepared by an analyst at his desk, or with a small amount of computer support. These are purely mathematical models which generally aggregate the actions which they examine, or else examine very limited aspects of the battlefield in detail. The detailed examination may be used as input to models of high resolution. Analytical models normally do not deal with an integrated battlefield.

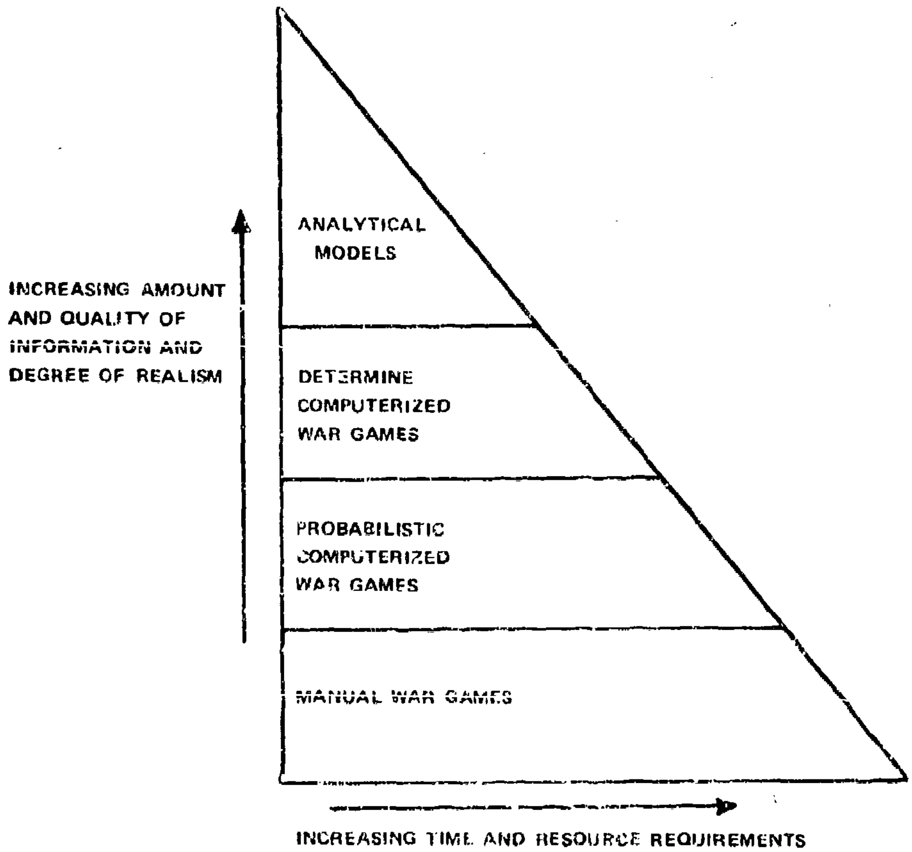

Figure 4-6 Analytical Tools (Combat Models) for Quantitative MOE

Analytical models may also be utilized to examine an entire force by use of "Lanchester equations." Analytical models of this type assume a known mathematical relationship between the size of two opposing forces and the rate at which they move and inflict casualties. Forces are aggregated. The mathematical equations ordinarily contain unknown quantities which must be obtained outside the model, usually from more complex models, experimental or combat data, or assumed relationships.

Analytical models of a force are "expected value" models, i.e., they consider that over many situations a probability is equivalent to reality. For example, if the probability that a soldier will detect a target at 300 meters is 0.3, the expected value assumes that in every 100 opportunities, the target will be detected 30 times. This is an averaging method which may be suited to a single sensor looking at a single target (one-on-one duel), but may give a misleading picture if there are many sensors looking at many targets (force-on-force).

- Deterministic Models

The deterministic model is an "expected value" model. It is a sophisticated extension of the analytical model of a force which incorporates terrain considerations, higher degrees of resolution of elements, and periodic examinations of the situation, which permits updating and more detailed examination than is possible in a purely analytical model. It becomes a practical model because of the computer. Model play is broken into a series of small time steps (e.g., 10 seconds each) and the situation of the forces is updated for that period. A considerably greater insight into an operational situation is possible than with a purely analytical model. The deterministic simulation can be viewed as a series of analytical models which are constantly updated to meet a changing situation. It can normally be run very rapidly on the computer.

Like the analytical model, the deterministic model uses "expected value" rather than probabilities. For a given initial situation, the deterministic model will always give the same answer in terms of MOE. A battle history can be obtained, but it may be difficult to relate it to the military user because portions of individuals can be killed and the remaining portion continue to operate. If, for example, the expected value is 0.3 that a Tube-launched, Optically-tracked, Wire-guided weapon (TOW) will kill an enemy tank at a given range, then every time a TOW fires at a complete tank it will kill 0.3 of that tank, leaving 0.7 still operating. The next time the TOW fires at the 0.7 tank it will kill 0.21 of the tank, leaving 0.49 of the tank in the play, and so on.

Since all systems suffer degradation proportionate to the appropriate expected value, before the model has gone very far most elements have values less than one, so that the battle history loses significance unless the mathematics can be followed. From a purely mathematical basis it has been demonstrated that the deterministic model gives valid results for large forces. It is generally conceded that it also gives valid results for small unit, high resolution situations.

Deterministic models have gained wide use because of their speed of operation and relative simplicity and their technical aspects are well understood by analysts. These models require update and comparison to other models or real world situations to provide the mathematical unknowns inherent in their solutions, which may be a time-consuming process detracting from the speed of response offered by the deterministic model. In general, the deterministic model should not be used as the principal model to support a Military Worth Analysis if a probabilistic model is available. If its limitations and complexities are understood, the deterministic model can be valuable as a supplement to perform rapid excursions and parameter analyses to expand the efforts of the primary model. Because of its inherent limitations, a deterministic computerized model cannot be dynamic and still retain its responsiveness.

- Probabilistic Models

The probabilistic model plays the probabilities which occur in the real world, usually by means of the "Monte Carlo" technique. When a probability occurs, a random number is selected. If it is within the range of probability, the event is considered to occur; if outside, then the event does not occur.

If the probability is 0.3 that a TOW will kill a tank, then each time a TOW fires at a tank, a random number is pulled from tables set up for that purpose. If the number is three or less, the target is considered to be killed. If the number is greater than three, the target is considered to have survived. Whole elements are killed; the partial elements of the deterministic model are eliminated and the battle history conveys real meaning to the military user.

In the play of an integrated force, thousands of probabilities may occur. It is clear then that for each play of the model, a different MOE output can occur as would be true in real life.

The probabilistic computerized model has a slow response time, but it plays the highest resolution and gives the most realistic play of any computerized simulation.

- Manual War Game

Computerized models of the integrated division battlefield have not been produced successfully to date, although the effort continues. Therefore, with larger forces, the choice must be made between using "pure" computerized models, or resorting to the manual war game if an integrated battlefield must be played.

The manual war game has a long history and was used successfully by the ancient Romans and Chinese, as well as by modern armies. Manual war games at the battalion and lower levels have been generally superseded by computerized simulations, but manual war games are still the primary analytical tools for large forces. They are particularly valuable in

examining problems presented by integration of systems into a large force. The assistance available from the computer has eliminated much of the drudgery from manual war games and speeded them, but those games which produce convincing results still consume large amounts of manpower and time. Accelerated games (jiffy games), which can play a day of division combat in one or two days of game play, have been developed and have some uses for rapidly obtaining generalized information, but are usually inadequate to support a Military Worth Analysis.

Manual war games require a knowledgeable player staff, analytical support, a map room, a set of rules, and computer access. When these are available, they can produce what amounts to a high resolution examination of large forces. While some manual war games use inputs from high resolution battalion models, the newer ones play the division game as the division commander might see it, with variations within the division dependent upon the situation of each individual unit. Because of its size, the manual war game is a deterministic model, which is quite acceptable for larger forces.

The key factor in the manual war game is the group of selected military players who, within the rules of the game, take their actions in a logical manner based on the combat situation being gamed. The manual war game is dynamic and possesses a high degree of realism. Most high resolution models play short, high intensity battles. The manual war game plays a day or more of combat, and hence can show the effects of the candidate systems under sustained operations. Perhaps its greatest value is in examining the impact of constraints. As an example, scatterable mines may look good in a high resolution simulation, but in a manual war game they may not show up as well due to non-availability of artillery to deliver them. Since manual war games consume so much time, they should be included in a Military Worth Analysis only when adequate lead times are available.

4.2.2.3 Measure of Performance and Data

The measure of performance (MOP) used to describe camouflage performance in a Military Worth Analysis is dependent upon the structure and requirements of the combat model. If the model is written in terms of mean range to detection, it is futile to try to force the model to accept data in terms of search time. Section 6 of the Guide contains specific information on measures of performance and the tests used to obtain data for use in the combat models. The measures of performance generally used to describe camouflage performance are "range of detection" and "time to detection".

4.2.3 Parametric Analysis

The purpose of the models used in the Military Worth Analysis is to relate the camouflage measure of performance to the measure of effectiveness of the force containing the camouflage. The straightforward approach is to

determine values of the MOE for known values of the MOP which describes candidate camouflage treatments, and then to plot the relationship as shown in Figure 4-2. But this relationship between effectiveness and performance can be determined by a parametric analysis without considerations of specific camouflage designs.

A parametric analysis consists of selecting reasonable, arbitrary values of the MOP without consideration of what camouflage treatment would accomplish this MOP, and of determining the MOE associated with each. The range of MOP values selected should cover all cases of interest.

Parametric analyses serve two purposes; they save time and indicate trends. A developer does not have to wait until all the test data is in before the Military Worth Analysis can be performed. Experience or reasonable estimates will allow the parametric analysis to bracket the anticipated test data so that when MOP test data is available, the related MOE may readily be determined. In situations where it is impractical to obtain test data, a series of arbitrary choices of the MOP would indicate trends in the MOE. In some cases, slight decreases in the detection range might have a significant influence on battle outcome. In other scenarios, such as preplanned artillery strikes, near-invisibility of an item would not provide protection.

Models are designed to be sensitive to variations in characteristics of systems. It might be expected that if the accuracy of a rifle is improved, it will produce more hits which will show up in the model output. Due to design failures or unanticipated interactions with other factors, it may be found that the model shows no significant increase in hits for the more accurate rifle. The model is then said to be insensitive to rifle accuracy. There are many aspects of lack of sensitivity, but the most important ones fall into two categories:

a. The model is poorly designed and is insensitive in areas where it would be expected to show variation. In other situations it may show an extreme increase in output for a nominal change in input, in which case it would be overly sensitive. In these situations the model is producing invalid results and needs modification. Care should be used that the estimate of what should happen is logical and unbiased.

b. The model is properly designed but the new system is not producing a significant change in the effectiveness of the force. As an example, consider a battle between two integrated forces, both of which contain armor and mechanized infantry. The measure of effectiveness is the number of enemy armored vehicles destroyed. Candidate automatic cannon systems are being examined in the Military Worth Analysis, and it is found there is no significant change in the MOE among any of the candidate systems, i.e., the model cannot distinguish among them. Inability to distinguish between candidate systems is not the same thing as being insensitive to changes in their performance, and a deeper examination must be made before the model design is faulted.

In the cited case, since an integrated battlefield was being played, enemy armored vehicles were destroyed by friendly tanks, antitank weapons, artillery and mines. There was little left for the antomatic cannon to destroy and their varied performance produced differences of only one or two armored vehicles in the MOE, hardly significant against a force of 40 enemy armored vehicles. While the model could not discriminate between candidates, the model was painting a true picture on the basis of the MOE given, and hence other MOE or some other method of assessing effectiveness should be used. In this case it was determined that end result MOE (Level II) would not distinguish between the candidates; and a different measure, specifically supression, was used.

A program for assessing sensitivity as a means of ensuring that the model is producing valid results should be included in the Military Worth Analysis plan, and should be a critical element of the model update. Sensitivity of the model to as many critical aspects as possible should be analyzed within time and resource constraints.

4.2.4 Military Worth Analysis Output

The output of a Military Worth Analysis is a relationship, as shown in Figure 4-2, between the input measures of performance (MOP) and the measures of effectiveness (MOE) calculated from the output of the combat model. Analysis of this relationship indicates how much effect a camouflage treatment of the developer's item/system has on the outcome of the military operation played in the combat model.

The Developer may have a requirement for a definite reduction of the effectiveness of the hostile surveillance threat. This would be expressed as a definite change in the MOE. For example, in Figure 4-2, the improvement in MOE from the uncamouflaged Treatment #1 to the camouflage Treatment #3 may be the minimum acceptable improvement in MOE so that no matter how small the cost of camouflage Treatment #2, it just does not do the job. Also, if the graph exhibits a "knee" such as at camouflage Treatment #4, there is little additional advantage to be gained by camouflage Treatment #5 which has a greatly different perceptibility. Thus, effectiveness considerations alone may determine which of several camouflage treatments are accepted for further development.

The outcome of this Military Worth Analysis forms the basis of specifications for particular levels of camouflage performance stated in terms of the measures of performance. These camouflage performance goals are considered in the Concept and Analysis Study.

4.3 CONCEPT AND ANALYSIS STUDY

The Concept and Analysis Study consists of several proposed camouflage designs or treatments which are expected to achieve the desired

measure of performance, and includes estimates of the costs and other factors associated with the concepts. See References 6, 7, and 8 for recent examples of this type study.

The camouflage technology contained in Section 5 of this Guide represents a good starting point for concepts and designs to defeat a threat sensor. Camouflage needs for which there is no existing technology would then be identified as the object of a camouflage research and development program.

The cost of each concept should include not only the cost of development, testing, and production; but should include other "costs" such as that of the troop labor to install or maintain the camouflage and that of the burden added to the logistic system by the camouflage. Excessive costs of a concept may exceed some externally imposed cost ceiling and prohibit the use of a concept regardless of its effect on the outcome of a military operation.

The final factor to consider is the compatibility of the concept camouflage treatment with the operation of the item/system. Most camouflage treatments impose some slight penalty on the item/system in the form of increased weight or bulk, demand for storage space, reduced efficiency of power supplies, or reduced reaction time or mobility. Designs to improve compatibility will reduce these penalties to the minimum.

The conclusions of the Concept and Analysis Study and of the Military Worth Analysis form a basis for a statement of camouflage goals in a requirements document.

4.4 EXAMPLE PROBLEM

An example illustrating the material discussed in this section is located in Appendix A in this Guide.

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SECTION 5

COUNTERMEASURE DEVELOPMENT

This section presents the concepts upon which camouflage methods are based, and then describes available camouflage methods, techniques, materiel, and materials. The presentation of camouflage methods and techniques is followed by an example which shows how camouflage is chosen and applied to the sample problem discussed in Section 4.

The subject matter treated in this section presumes that the camouflage problem has been researched and defined as precisely as possible; and that detection, recognition, target acquisition, and hitability threats have been determined, as has the perceptibility of the uncamouflaged item/system. The procedures for determining countermeasure goals were described in Section 4.

While the developer remains responsible for the development of countermeasures for his item/system, one mission of the Camouflage Laboratory is to assist in this effort. Such assistance can be provided at any level from minor consultation using MERADCOM in-house funding to complete development of a camouflage treatment for the item/system using Developer funding.

5.1 COUNTERMEASURES

5.1.1 Definition

Countermeasures are defined as a "form of military science which by the employment of devices and/or techniques has as its objective the impairment of the operational effectiveness of enemy activity."* Countermeasures are, therefore, applicable to item/systems which may be thought of as either offensive or defensive in terms of primary mission.

Qualifying adjectives are often used in reference to countermeasures (e.g., active, passive, electronic, etc.), in an attempt to improve clarification. Agreement is lacking in many cases as to whether a particular countermeasure is active or passive. Smoke is a good example since it is often classified as either active or passive depending upon the user's viewpoint. Smoke may be thought of as blinding the enemy, or hiding the target. Therefore, the terms "active" and "passive" countermeasures must be used cautiously.

Figure 5-1 depicts the field of countermeasures related to detection, recognition, identification, and location. The groupings shown in Figure 5-1 separate those countermeasures which are intended to prevent observation from those intended to affect observation.

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* Dictionary of Military and Associated Terms, JCS Pub. 1, 3 Sept 1974, p. 91

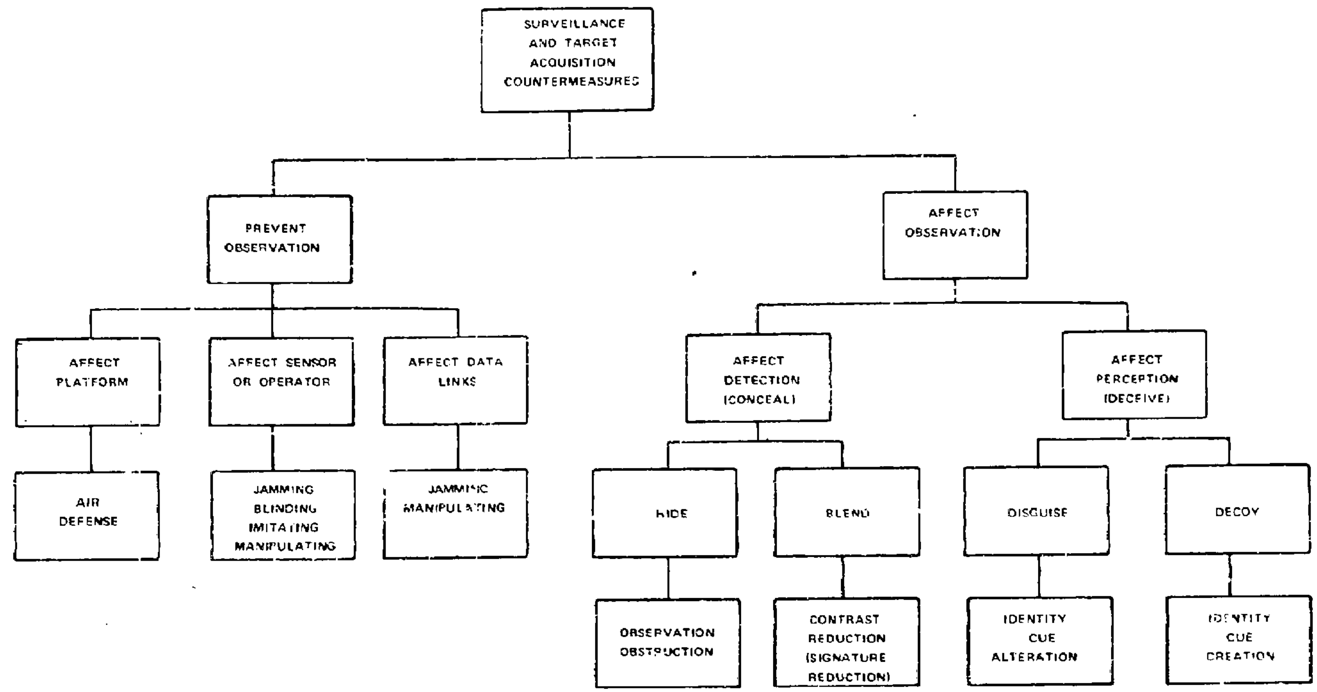


Figure 5-1 Countermeasures Related to Target Detection, Recognition, Identification, and Location

5.1.2 Countermeasure Interfaces

The boundaries (or interfaces) between camouflage and other countermeasures are often defined by authority for the practical reasons of allocating responsibility for their development, deployment, etc. Definitions that are based purely on technical grounds will appear inconsistent in these situations. Figure 5-2 illustrates the countermeasure fields having contiguous boundaries with camouflage. Tactical deception and electronic warfare are discussed further to clarify their interface with camouflage.

5.1.2.1 Tactical Deception Interface

The terms "deception" and "tactical cover and deception" have a very specific meaning in U.S. military parlance. The latter term is a part of operations, is generated as part of operational planning, and is put into effect through annexes to field orders. It is offensive in concept and while it may be thought of in terms of protecting friendly operations, it is normally considered in a weapons or force sense. Tactical cover and deception is aimed at convincing an enemy command that some capability or intent is truth, when in fact, some other capability or intent is truth -- in an operational sense. For example, the intent may be to convince the enemy that an action, the preparation for which is not deniable, will take place on the 21st, when in fact, it will take place on the 15th.

Tactical cover and deception then is a command tool and succeeds only if the enemy does what the friendly commander intended him to do. Electronic warfare, decoys, etc., may or may not be utilized in creating tactical deception. In many cases, the same physical simulation hardware may be fielded as a camouflage method for a weapons system, and also on occasion serve in a tactical deception role. For example, a camouflage screen poorly emplaced may serve as a decoy.

Camouflage is protective in concept and its generally accepted meaning is "to conceal or deny truth." The use of the camouflage terms *disguise* and *deception* (decoy) is also protective in concept and intended to reduce detectability and hitability through confusion of numbers, locations, and ability to attract fire -- especially if some degree of concealment can be achieved for the real item at the same time. For example, if a weapon necessarily emits a signal which can be used as a locator through triangulation or other techniques (direction finding, flash and sound ranging), or as a signal for homing missiles, then decoy emitters, emplaced and operated in conjunction with the real weapon in a manner that confuses such triangulation and homing capability, constitute a protective camouflage measure which is no different in intent from camouflage screens or pattern painting.

The employment of decoy signals and/or equipment is generally the responsibility of the unit using the archetype material. Decoys used in a camouflage sense may be signals, physical surface replicas, electromagnetic emitters, noise makers, and other signature cue emitters, and; in fact,

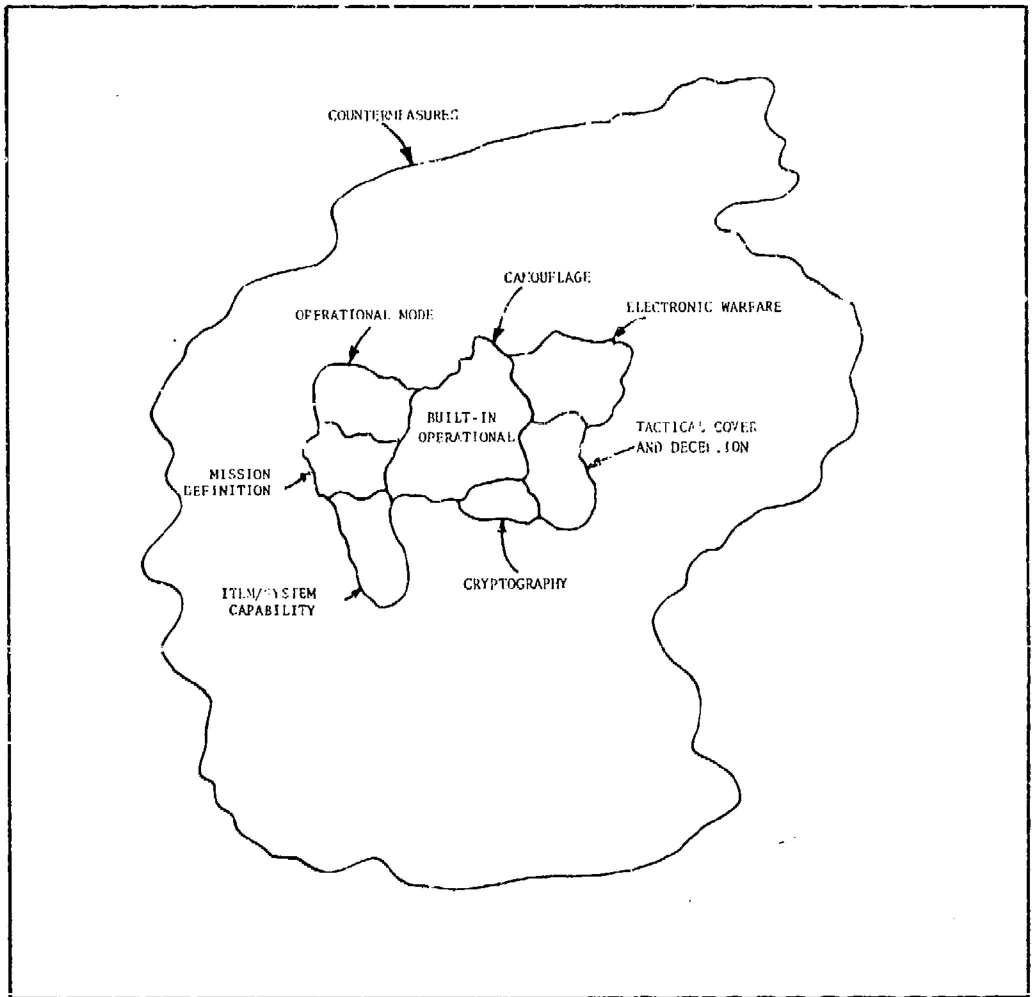


Figure 5-2 Countermeasure/Camouflage Interfaces

decoys may be any form of simulation. If the decoys are used to protect materiel of similar kind and are intended for employment by units employing the archetype equipment, they are a camouflage method and bear no direct relationship to tactical cover and deception.

5.1.2.2 Electronic Warfare (EW) Interface

Electronic warfare began in a formal sense during World War II and was primarily concerned in its early stages with radio messages and anti-radar measures. Figure 5-3 shows that, like camouflage, it includes denial, disguise and deception. Unlike camouflage, however, electronic warfare has an intercept and surveillance role.

EW is defined as "the military use of electronics involving actions taken to prevent or reduce an enemy's effective use of radiated electromagnetic energy." It is called electronic because it initially involved the use of electronic equipment in the search, interception, location, identification, and analysis of hostile emitters, from extra low frequencies (ELF) through the ultraviolet (UV). EW uses electronics to jam and deceive hostile receiving and processing systems, as well as the use of flares, chaff, and retroreflectors.

The field of EW has an area identified as electronic counter-countermeasures (ECCM) to achieve anti-jamming capability in U.S. systems. In this latter role, EW is concerned with determining the vulnerability/susceptibility of U.S. and certain foreign electronic and weapon/missile systems to hostile EW/SIGINT techniques.

Electronic warfare is not treated in this Guide, although some camouflage materials such as radar absorbing materials (RAM), radar scattering screens, and certain forms of shielding might also be employed as electronic counter-countermeasures (ECCM). One area of electronic warfare, which is also within the purview of camouflage, is the creation of necessary electromagnetic emissions that provide decoys with realistic signatures. For example, a continuous wave radar decoy used in a Hawk battery camouflage design that never emits a radar signal will not provide effective deception. Providing the required radar signal is a necessary camouflage technique, however, providing the radar transmitter is a function of ERADCOM.

5.2 THE NATURE OF CAMOUFLAGE

Camouflage is the intentional denial and misrepresentation to enemy observation of objects, signatures, signals, or other evidence, and is normally achieved through hiding, blending, disguising and decoys. It is, therefore, a form of counterintelligence. According to AMCR 70-58, camouflage includes the application of passive measures to reduce perceptibility to surveillance.

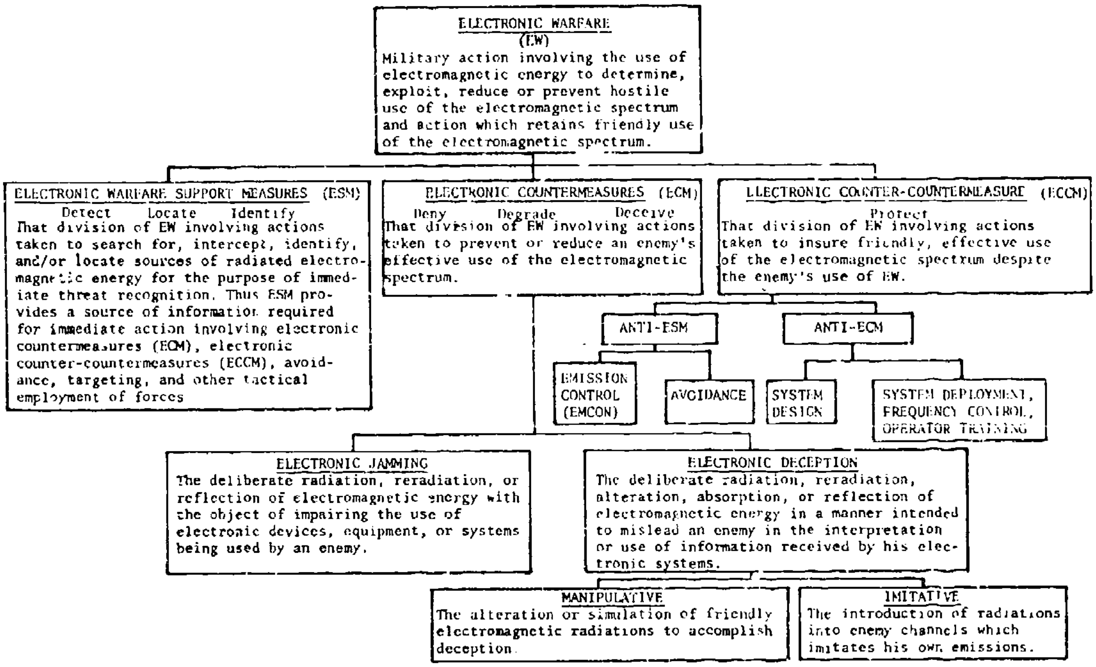


Figure 5-3 Electronic Warfare

The generalized differentiation between camouflage and other countermeasures is that camouflage does not deny the use of remote sensing means or interfere with their internal operation. Camouflage decoying techniques depend upon observation to transmit misleading information to an enemy in order to conceal truth. Camouflage deals only with the information which remote sensors and observers process.

Effective camouflage is the product of camouflage consciousness in a number of areas. This is especially true in the case of applying camouflage to operational characteristics, or to item/systems in the field. Camouflage consciousness is the product of command emphasis, discipline, training, techniques, and materiel. Failure in any one of these areas can impact camouflage effectiveness. Concealment may be employed to increase item/system survivability by reducing its detectability and hitability.

Concealment is also used in combat to achieve surprise. This includes surprise with respect to the individual, an entire force, and intermediate units. Although the advantage of surprise cannot be precisely quantified, military tacticians recognize "surprise" as a favorable factor in the power relationship of an engagement.

When applied to camouflage, the term *passive* means that no attempt is made to prevent observation. Although the objective of preventing observation may be laudable, the techniques for achieving this objective are not within the scope of camouflage. Conversely, however, all passive countermeasures cannot be considered as camouflage. For example, certain passive countermeasures in the area of electronic warfare are not considered to be a part of camouflage; not because of differences in intent, but more because of a technology difference. Likewise, cryptography, a passive form of concealment is seldom considered as camouflage.

The word perceptibility was adopted into the camouflage lexicon to indicate those characteristics, states, or quantities of an item/system (and its operation) which cause it to be detectable, identifiable, locatable and hitable through surveillance and target acquisition means. The purpose of camouflage is to change the perceptibility of an item/system to make it less detectable, identifiable, locatable and hitable.

5.3 THE SCIENCES OF CAMOUFLAGE

The interface between camouflage and sensor threats involves the sciences of physics, psychophysics, and psychology. The phenomenon of energy transfer which occurs from the energy sources to a target and eventually to a sensor is governed by the physical laws involving electromagnetic and mechanical energies and chemical dispersion. Psychophysics treats the mechanisms and limits of the internal human systems used for processing external energy variations which impact sense organs (eyes, ears, etc.). The internal processing of energy variations, which impact the transducer element in modern remote sensing systems, has much in common with psychophysics and both concern communications theory. The special fields of psychology concerned with camouflage are perception and the behavioral processes which affect awareness and identification.

One of the difficulties of camouflage design and evaluation is that camouflage encompasses physical, biological, and behavioral sciences. A very brief description of the role of these sciences with respect to camouflage follows.

5.3.1 Physics

The laws of physics govern the energy exchange by which military targets are detected and identified, primarily through the principles of energy propagation, reflection, absorption, and emission (Figure 5-4). The physical methods of energy exchange with which camouflage is concerned include the electromagnetic and mechanical (sonic and seismic) spectrums and chemical dispersions. Some understanding of these disciplines is necessary if the design and application of camouflage is to successfully exploit, for concealment purposes, the energy exchange principles and laws upon which sensors operate.

At this basic physical level, camouflage is concerned with preventing, reducing, shielding, or otherwise controlling in a directional sense, the energy emitted by and/or reflected from material. The medium through which the energy must travel to reach a sensor also affects the energy in various ways, and this effect must be recognized to allow for the attenuation and refraction of the energy prior to reaching the sensor. For example, engine vibrations cause a flow of energy through the air in the form of waves. Variations in the air density, wind direction and speed, moisture and other impurities such as dust or smoke in the medium, and reflections from the ground and other objects all affect the nature and quantity of energy reaching any remote sensor.

Finally, a knowledge of the ultimate sensitivity and resolution of sensors is necessary to determine levels of energy which must be denied under given conditions. Sensitivities to both amplitude and wavelength is of concern. For example, the energy transmitted from a target might be shifted to a band of frequencies which the medium absorbs or to which the sensor is insensitive.

5.3.2 Psychophysics

Psychophysics is a branch of science that deals with the problems common to physics and psychology. It is the understanding of this process that provides further knowledge of how to treat materiel to deny or confuse the data resulting from psychophysical processing. For example, human vision has certain resolution limits, contrast discerning limits, and spectral response limits as does photography or any other sensor system. Camouflage attempts to capitalize on the discrimination limits of the sensor systems by keeping perceptible data from the target below the contrast resolution and sensitivity thresholds of sensor systems at their operating ranges under the expected environmental operating conditions.

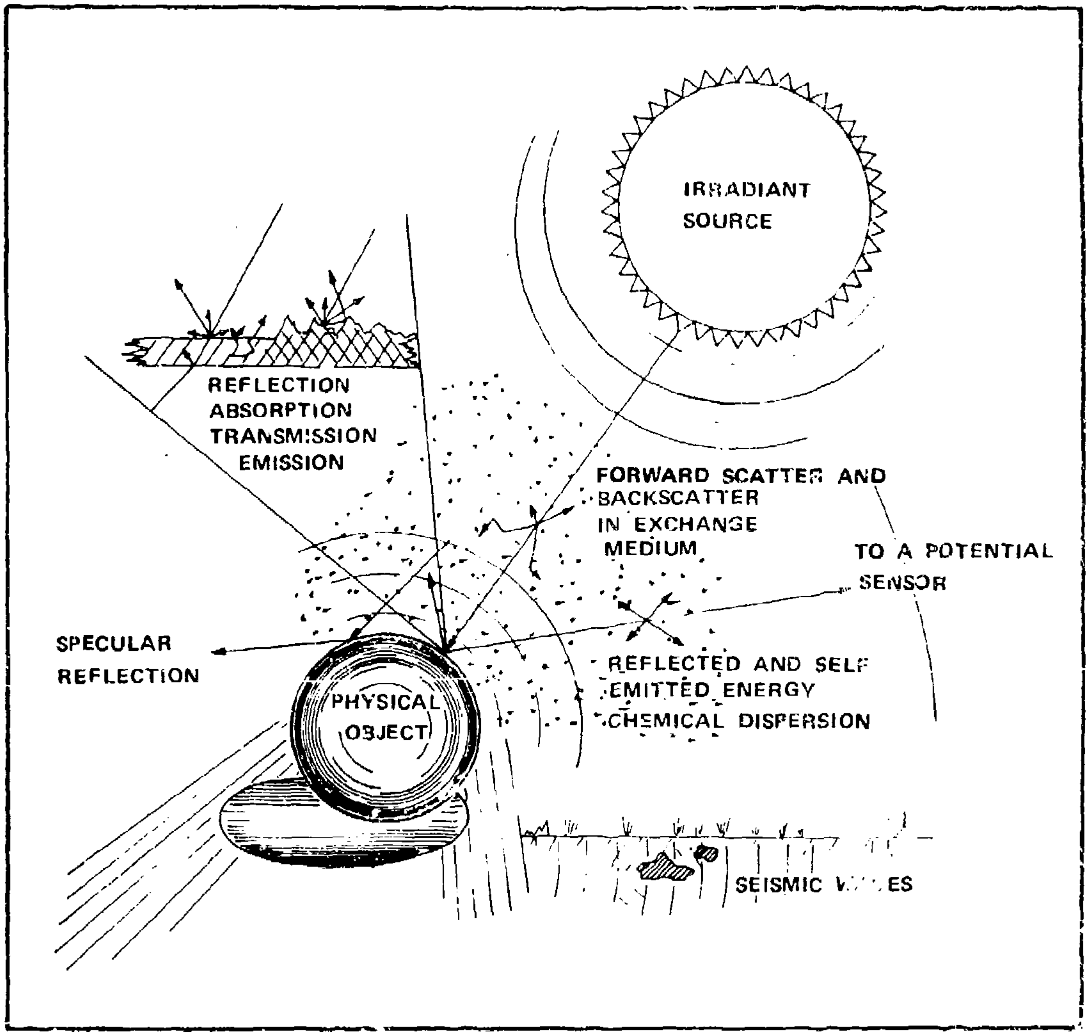


Figure 5-4 Physics

5.3.3 Psychology

For any remotely sensed data entering the brain (or other analysis system) to be useful in revealing a target, it must be perceived by an awareness. That portion of the field of psychology called perception is concerned with the mental process of awareness and identification. (Why didn't I see the stop sign? It was in plain view!) Humans constantly receive so much information that nature has devised a filter system which treats most of it on an automatic or rejection basis. Only through a phenomenon called attention are things perceived in a state of awareness. This phenomenon involves a combination of two factors -- identity and motivation.

Identity as used here is a function of memory, or stored data, against which incoming data is compared as it is received to produce some level of recognition. In this context, camouflage functions by modifying the cues which are used to classify the signals and objects observed so that by comparison to memory they will be falsely classified. This is most easily achieved when the modified cues form an image or comprehension to an observer that is easily recognized and is considered benign. There is a very powerful need in humans for recognition, and the mind will often fill in non-existing parts of an image or signal pattern to create a recognizable form or comprehension.

Motivation can be divided into instinctive reaction and purposeful intent. Subconscious defensive mechanisms are built into the human system so that, for example, rapid movement of a close object usually creates instant attention, awareness, and apprehension as instinctive reactions. An example of intent is that of an image interpreter assigned to locate aircraft in photographs of a suspect area. The interpreter will likely, in searching, be unaware of other items in the imagery. On the other hand, if he is given the task of searching the imagery for military objects, he will more likely be aware of all items that are not indigenous to the terrain being searched. In this context, camouflage attempts to use disguises which are not likely to arouse fear or concern in the observer.

Where it is not feasible to present a disguise that appears to be part of indigenous terrain or background, the disguise should portray something that represents a minimal threat to an enemy: Tanks are made to appear as trucks, but not vice versa.

Camouflage proposed for any item/system is usually some combination of treatments and techniques derived from the knowledge of these three sciences. This knowledge should lead to an understanding of why texture is applied to surfaces, why particular colors are chosen, why cue disrupters are used, etc.

5.4 THE TASK OF CAMOUFLAGE

Intelligence on the battlefield is normally obtained by coupling an analysis of the data obtained from remote sensing means with general or background knowledge relative to a hostile force's overall capability and

intent. In order for remote sensing systems to accomplish their surveillance and target acquisition mission, three processes must occur:

- The sensing device must be capable of discriminating differences between characteristics of the target and the environment in which the target is located - and it must be able to display these differences.
- Some intelligence, human or otherwise, must then detect these differences in the display.
- Finally, some form of intelligence must decide if these differences represent an object or activity of military interest.

Camouflage is primarily aimed at reducing the level of identification that can be derived from the data obtained through the remote sensing system by:

- Reducing threat contrast to levels which sensor systems are incapable of discriminating or displaying.
- Reducing target contrasts to levels that cannot be detected on sensor system display, or
- Minimizing signatures or cues to deny or delay target identification.

Camouflage methods are divided into two groups which reflect a two-phase concept of reducing perceptibility. The first group includes those methods and techniques which defeat the sensor by reducing target contrasts to levels which sensor systems cannot discriminate. These methods are designed to defeat both the remote sensors and the psychophysical capabilities of observers, and employ techniques which are based on knowledge of the sensitivity, frequency response, contrast levels, resolutions, edge discrimination, etc., of the remote sensors involved.

For example, assuming no physical obstruction to observation, a tank painted white observed against a green foliated background can be detected visually in a clear atmosphere during daylight at a range of several miles. By utilizing knowledge of the limits inherent in human visual capability, the detection range of the tank can be dramatically lowered by painting it a dark color (Figure 5-5).

By further reducing the contrast and adding pattern painting to the tank, the detection range is further decreased. The detection range can be progressively diminished until a point is reached where no further amount of surface treatment will prevent detection. The inherent bulk of the item and shadows cast on itself and its background provide such strong cues that no surface treatment can prevent a high detection probability at close range. The addition, however, of shape disrupters and shadow casting materials can provide reduced detection ranges, below those achievable with surface treatments alone, by altering the continuous and form-revealing shadows.

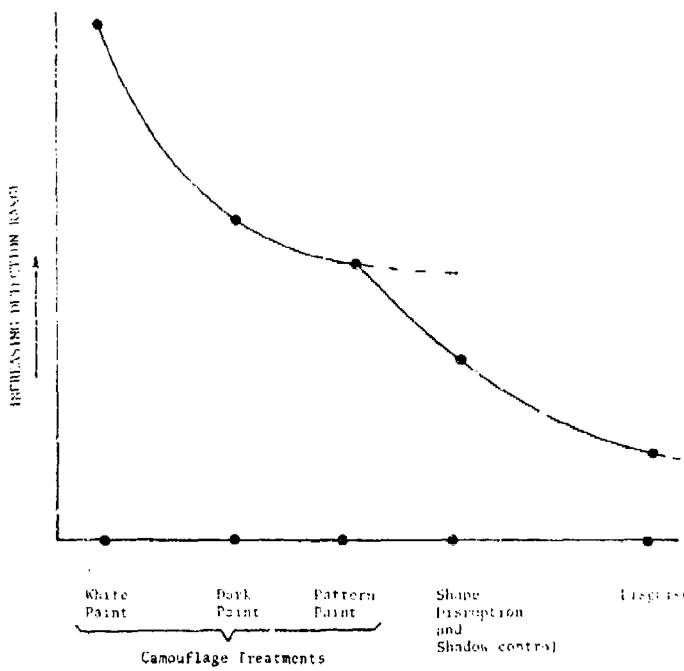


Figure 5-5 Tank Detection Range

A method of reducing perceptibility other than by hiding or blending is illustrated by treating the same tank to appear as part of its background (through application of disguise). The observer will likely fail to comprehend its presence even though it is in plain sight at close range.

The second group of camouflage methods begins with the hypothesis that reduced range, multi-sensor use, and extended search time will produce a condition where the presence of nearly anything of a military nature will be detectable unless it is somehow purposely concealed. Therefore, a major effort should be made to alter cues from which identity conclusions are formed by enemy observers and homing devices.

The principle of perceptibility operates by making the tank appear as an object which is not a threat to the observer, i.e., an innocuous item of little consequence in the battle context. The observer's perceptive attention threshold is not likely to be crossed and the observer may not even be aware of the disguised tank's presence. Consequently, camouflage must incorporate the concept that it is the awareness of truth that is to be confused and denied, and not be limited to simply reducing the ability to sense an item's presence.

This aspect of camouflage, therefore, deals with defeat of the perception of targets and activities, not by defeating the remote sensor itself, but by defeating the analysis and conscious awareness of what is observed or recorded through the sensor. This is true for items/systems themselves, their ground pattern, operational procedures, and even their spoor.

Progressing one step further, there will inevitably be items/systems which by their nature, are not amenable to hiding, blending or disguise. Survivability and surprise potential for those items/systems can often be improved through denial of truth by the use of decoys and deceptive techniques which, if fielded with all necessary signatures, can create confusion and draw fire on the decoy. The most effective use of decoys occurs when the decoy is a more attractive target than its archetype.

5.5 TYPES OF CAMOUFLAGE

The historic concept of camouflage being field applied by troops using local materials or those supplied from standarized camouflage inventories has been found inadequate to counter many of today's surveillance and target acquisition capabilities. As the lethality and accuracy of weapons increases, the ability to remain concealed becomes more important to survivability and mission success.

Many of today's surveillance and homing systems depend on signatures which are beyond the effective control of the employing troops, and which may not even be recognized as important by the troops. The situation, therefore, requires that effective suppression or disguise of these detectable and identifying signatures must be dealt with by technical personnel. It is axiomatic that the earlier in the life cycle the signature cue problems are identified, the more likely that practical solutions will be found and applied. This has lead to the concept of "built-in" camouflage according to AMCR 70-58.

5.5.1 Built-In Camouflage

The term *built-in* is meant to include all materiel and procedures designed into the item/system. This may include attachments or accommodations for the use of standardized camouflage materiel such as the standard modular screening system. However, there will likely be many design features or materials used which will not be recognizable or inventoried as "camouflage materiel." The important point is that the perceptibility of the item/system will be within militarily useful limits when it is fielded. Further, this built-in concept includes the employment, doctrine, training, and operational standard operating procedure designations required to permit maximum utilization in worldwide terrains and the proper exploitation of terrain to further minimize detection and hitability.

No one is better qualified to determine built-in camouflage for an item/system than the developer, but a few camouflage possibilities are mentioned to assure understanding of the terminology.

- Thermal shielding, insulation, or dissipation
- Flash suppressors
- Smokeless propellant

- Silencers, mufflers, sound deadening panels
- Oblique metal surfaces
- Recessed or covered lights and optics
- Low silhouette
- Droppable windshields
- Fabric with textured camouflage patterns imprinted
- Wrapping paper printed with camouflage colors

Built-in camouflage which is retrofitted to existing equipment may be thought of as "add-on" camouflage. This could include repainting if the equipment were painted at the factory, or devices such as flash suppressors, mufflers, RAM, etc.

5.5.2 Operational Camouflage

Operational camouflage is concerned more with elements of training and discipline than with materials. Operational camouflage can be responsive to a local situation with respect to tactics, position and background and may include the proper use of natural cover and shadow, concealment of tracks, proper use of mutual cover and shadow, concealment of tracks, proper disposal of litter, blackouts, the control of noise and dust, movement, etc. Although many aspects of operational camouflage are beyond the equipment developer's control, he should be cognizant of what it can provide for the item/system, and what can be done to enhance operational camouflage through development of standard operating procedures for the item/system.

5.5.3 Field Applied Camouflage

Camouflage applied by troops in the field to themselves and their equipment continues to be an important type of camouflage. This is necessary to optimize local blending of color and materials and to complement the local tactical situation. Examples of this type of camouflage include the soldier who blackens his gunsight, paints his face, or garnishes his helmet with twigs and leaves. Brush might be used to cover spoor, or camouflage screens or disrupters could be placed over equipment. Here again, this aspect of camouflage is beyond the individual equipment developer's realm of control, but his actions can influence the degree of usage for field applied camouflage and thus deserves consideration.

Examples of the equipment developer's influence on field applied camouflage include such matters as providing storage space, hooks, or support points for camouflage screens or disrupters; eliminating exposed hot surfaces which would not stay painted; and making provisions for smoke cannisters (and possibly firing circuits).

5.6 CAMOUFLAGE METHODS AND TECHNIQUES

The application of camouflage involves the use of specific methods and techniques. Methods refer to the four classic broad categories of camouflage (hide, blend, disguise, and decoy), whereas techniques refer to detailed procedures employed to achieve these methods. Camouflage proposed for any item/system will usually be a combination of these four methods rather than a single one. For example, the employment of a camouflage screen to conceal a truck in a natural background involves *hiding* the truck beneath the screen through shadow casting. The screen is designed to *blend* with the characteristics of foliated areas by its color, texture, and pattern design to appear as a continuation of the terrain. The categorizations of hide, blend, disguise, and decoy help in deciding what form the camouflage solution to a particular problem should take. If, for example, the camouflage method selected for a gun emplacement is *hide* it would follow that the installation of an opaque screen over the emplacement is one of the techniques by which the method can be achieved. Figure 5-6 provides a generalized listing of techniques applicable to the four categories of camouflage methods.

5.6.1 Hide

Hide is the camouflage method by which an activity, signal, or emission is denied to a sensor through shielding, blackout or other techniques utilizing knowledge of the incapabilities of the sensor. Table 5-1 provides listings of specific hiding techniques, along with typical examples.

5.6.2 Blend

Blend is the camouflage method which reduces the contrast between an item/system and the background against which it is observed, and is generally related to surface treatments and the control of emissions/reflectivity by selection of texture, pattern arrangements, etc. Table 5-2 provides listings of specific blending techniques and typical examples.

5.6.3 Disguise

Disguise is the camouflage method that denies the validity of recognition by presenting a false appearance, and thus denies the truth. The suppression and obscuration of existing identity features and the substitution of others intended to cause a false identification is involved. This method usually takes one of two forms: either an attempt to give the item the appearance of background in which it will operate, or that of an object of reduced or no military consequence. Refer to Table 5-3 for typical disguise techniques and general examples.

5.6.4 Decoy

Decoying is the camouflage method that denies the validity of a situation as opposed to an item. It is differentiated from disguise by the creation of separate signals, items or spoor representing some archetype, and is not simply the alteration of identity cues as in disguise. In camouflage, decoys

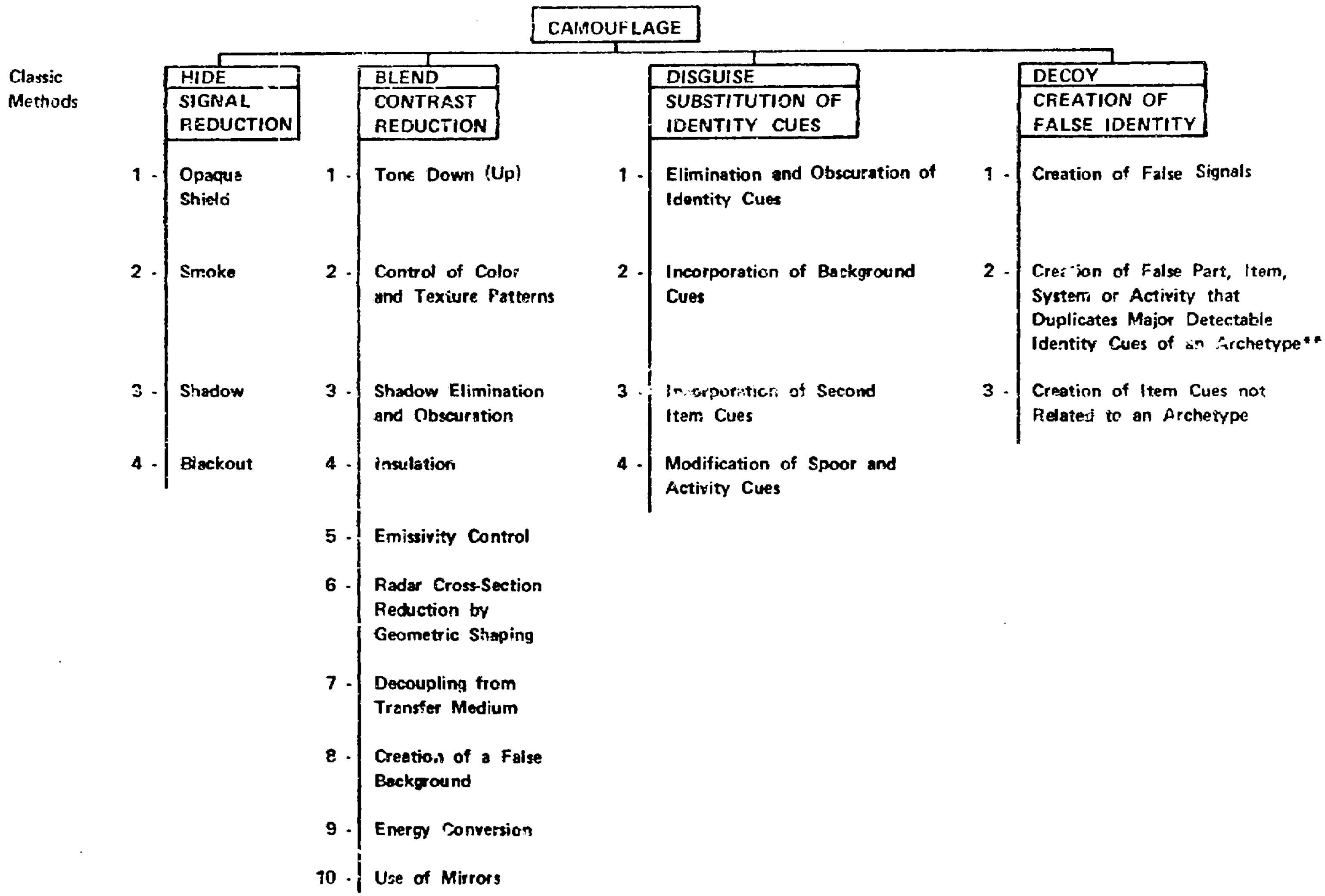


Figure 5-6 Camouflage Methods and Techniques

are used to suppress truth about a situation or installation for protective purposes, to divide fire, and to attract attention away from vital components. Examples of decoy techniques are given in Table 5-4.

Table 5-1

HIDE TECHNIQUES

TECHNIQUE 1

Use of opaque shields (natural or artificial) between target (or item/system) and sensor which prevent transfer of energy from reaching the sensor.

EXAMPLES:

Stand-off shields (insulated or otherwise treated) to permit convective cooling of a hot surface, and prevent transfer of energy from target to sensor.

Choosing a position which is not in view of potential sensors. Putting the item/system in defilade, in a barn, in an underground shelter, etc.

Bridges built under water in muddy streams.

NOTE: Additional information on hiding techniques is available in the 1000 series Data Sheets.

TECHNIQUE 2: SMOKE

A suspension in the transfer medium (air-water) that produces an opaque shield by absorbing and scattering the energy that is between a target and sensor.

EXAMPLES:

A smoke screen deployed by artillery or aircraft to deny observation of some activity, e.g., a river crossing.

Smoke created around a target by generators on the target when a sensor detects the presence of hostile illuminating energy.

Transparent smoke (aerosol) which absorbs and scatters in the IR region.

Creation of an instant opaque smoke wall by rocket or high pressure jets to deny visual acquisition of area targets as a final defense.

Use of highly absorbing gases around a radiating part. Due to dispersion, this is practical only where there is a means of containing the gas available or where the gas is required for only a limited time.

Table 5-1 (Contd)

HIDE TECHNIQUES

TECHNIQUE 3: UTILIZATION OF SHADOW

Positioning the target within a shadow such that the illumination level of the target is not within the recording capability of sensors using exposure times suitable for recording the general scene.

EXAMPLE:

Using the shadow of a building to hide a vehicle or weapon.

TECHNIQUE 4: BLACKOUT

The cessation of activity and emissions detectable to an enemy. (Applicable to intermittent and predictable observation.

EXAMPLE:

Shielding or disabling equipment that emits characteristic radiation, during the time a hostile satellite sensor is known to be in viewing position.

Table 5-2

BLEND TECHNIQUES

TECHNIQUE 1: TONE DOWN (UP)

This is the basic concept of contrast reduction wherein the signal strength or object reflectivity is decreased or increased to approximate the background.

EXAMPLES:

Application of dark colorants to a building located in a forested area to minimize contrast with the dark foliage.

Use of RAM (Radar Absorbing Materials) to reduce radar cross section.

Mixing of cool air into engine exhaust.

Use of mufflers to absorb noises.

Chemical or other means of suppression of muzzle flash.

Smoke suppression (oxygen balancing).

Application of colorants to packaging materials, cans, clothing, etc., for use in combat area to eliminate high visual contrast. This is expecially helpful for kitchens and other personnel activities.

Minimizing friction between moving parts to prevent heating.

Use of photochemical colorants and surface textures to modify the luminance of the target and its inherent shadow.

Use of texturing to reduce surface tonal variations.

Table 5-2 (Contd)

BLEND TECHNIQUES

TECHNIQUE 2: CONTROL OF COLOR AND TEXTURE PATTERNS

The creation of patterned areas of color and texture on an object to reduce its contrast with the background. This is a principal form of camouflage employed by many forms of life. It is often combined with shadow control. In many cases the pattern contrasts are high to further obscure the effects of shadow. There is a high correlation between the pattern and its immediate background which results in high detectability when the patterned object is moved to another background.

EXAMPLES:

The use of camouflage colorants to provide the spectral characteristics found in the backgrounds of military operations. This prevents spectra-zonal detection by remote sensors.

The application of textured leaf-like patterns over a shiny fabric for jungle combat uniforms. The depth effect is exaggerated and the camouflage effect is increased. Shine is a minor factor because the patterns break up any large areas of shine.

To be most effective patterns must duplicate the general shadow, high-light shapes and sizes in the background. By careful choice of color and texture, small patterns which are effective at close range will blend into larger patterns as the viewing range increases.

Patterns for mobile equipment must not be applied to wheels and other moving parts if a noticeable blinking effect is to be avoided. The luminance of patterns should generally not exceed the average background luminance.

The use of naturally-occurring local materials to permit blending with a greater number of backgrounds and seasonal changes.

Photochromic color coatings, which become transparent at night to reveal a second layer of camouflage and which darken in sunlight to form daytime camouflage, have been attempted but had a very short field life.

Table 5-2 (Contd)

BLEND TECHNIQUES

TECHNIQUE 3: SHADOW ELIMINATION AND OBSCURATION

Items are detected, i.e., separated from their backgrounds because of contrasts caused by structural outlines and shadows. Generally, under sunny conditions inherent shadow will overpower any pattern applied, thus revealing the item.

EXAMPLES:

Utilizing local brush or other material to fill in shadow and to disfigure the item's outline. Choosing positions which cause the shadows to fall on brush, or other shadow disfiguring material, or positioning on the shadow side of large foliage so the foliage shadow disfigures the item's shadow.

The use of artificial irregular attachments which will obscure inherent shadows of details and disfigure shadows cast on surrounding terrain (disrupters).

The use of reflected light from the sky to eliminate shadow. The item so treated must have a reflectance near that of the background or this technique will increase the target perceptibility.

The use of artifical light to eliminate shadow, thereby increasing the surface luminance to eliminate apparent form. These techniques have been used: (a) lamps have been placed within the shadow area, spaced close enough together to blend within the resolution capability of the sensor and controlled by a sensor viewing the background luminance; (b) Searchlights, shielded from view, which are directed into the shadow of the item to be concealed, and (c) Electroluminescent panels applied directly to the surface in shadow are useful only in low luminance levels.

The use of photochromic colorants which bleach in shadow and darken in sunlight (field modifiable colorants have long been sought but no practical materials has yet been produced) and photochromics which become transparent in sunlight to reveal an underlying camouflage.

Table 5-2 (Contd)

BLEND TECHNIQUES

TECHNIQUE 4: INSULATION

Insulation reduces the rate at which heat energy is acquired or dissipated, thereby preventing rapid variations in temperature - i.e., insulation smooths out the time-temperature relationship. Since many backgrounds against which items will be viewed tend to have long time cycles for thermal change, insulation will assist in preventing high contrasts.

EXAMPLES:

Insulation between hot parts (engine) and hoods or other enclosures is useful where the heat source exists for only short periods of time. Applied to the inner side of the enclosures, insulation increases the time required for heating the enclosures.

Insulating coatings applied to an item's surface reduce the rate of solar energy absorption.

TECHNIQUE 5: EMISSIVITY CONTROL

Emissivity control can be obtained by the use of coatings which radiate in spectral regions not subject to detection and by physical alteration of surfaces to redistribute emissions in preferred directions. The intensity of radiation in the thermal regions of the spectrum is a function of the surface temperature and the emissivity of the surface. It is possible to alter the spectral distribution from a surface and thereby reduce the item's IR signature by utilizing coatings which have low emissivity in the spectral window regions of 3-5 microns and 8-14 microns, but high emissivity in other areas. (This capability is limited and costly.)

EXAMPLES:

Control of IR emissions can be exercised by enlarging the surface and randomly configuring it to modify its directional radiating properties.

The use of thermal pillows which are flat on the inner side and pillowed to have an external area several times the inner and wrinkled to dissipate the radiation throughout more of the hemisphere above the surface.

The use of faceted IR transparent sheeting material of a suitable refractive index in the IR region, standing away from an item or surface, and designed to cause the radiation from the item's surface to be refracted in directions outside the field of view of a sensor.

Table 5-2 (Contd)

BLEND TECHNIQUES

TECHNIQUE 6: RADAR CROSS-SECTION REDUCTION BY GEOMETRIC SHAPING

The use of shields to cover cavities and the use of designs which eliminate 90° angles of the item's structure.

EXAMPLES:

Use of metal screen or camouflage screening garnish to cover cavities.

Avoid cavities in design where possible.

Use flat plate design where possible and join in angles greater than 90° if possible. For existing 90° angles, either cover with metal screen or fill with radar scattering camouflage cloth.

TECHNIQUE 7: DECOUPLING FROM TRANSFER MEDIUM

The isolation of a signal generator from energy transfer medium such as the air, water, or earth, and from the item of which it is a part to prevent the energy produced from entering the transfer medium and becoming available to the sensor.

EXAMPLES:

Isolation of an outboard motor from the boat to prevent the motor vibrations from reaching the large radiating surfaces of the boat.

Isolation of a heat source by surrounding it with a vacuum will eliminate convective heat transfer.

TECHNIQUE 8: ENERGY CONVERSION

The absorption of incoming or internally generated energy, and the conversion of that energy to a form which can be shielded, used, or converted to a type not subject to detection.

EXAMPLES:

Radar absorbing material (RAM) which converts the incoming microwave energy into heat.

Sound deadening material which converts acoustic energy to heat.

The use of coolants to absorb and dissipate energy.

Table 5-2 (Contd)

BLEND TECHNIQUES

TECHNIQUE 9: USE OF MIRRORS

Shaped and mirrored surfaces are used to prevent signal transfer to sensors. Mirrors can be made to blend with terrain by reflecting images of terrain, while items are hidden behind the mirrors.

EXAMPLES:

A plastic sheet with a mirrored surface deployed in front of a vehicle (or other object), almost normal to the direction of observation but tilted slightly forward, will reflect the terrain directly in front of the position back to the observer while hiding the vehicle. This is effective in trees where vertical lines of the trees tend to conceal the straight edges of the mirror.

The angling of surfaces, subject to known sources of radiation used to illuminate the object for remote sensing, such that the illuminating energy is mirrored toward directions other than back to the sensors employed.

TECHNIQUE 10: CREATION OF A FALSE BACKGROUND

In instances where cover or a confusing background is lacking, a confusing background may be created.

EXAMPLES:

In a dry prairie where there are few trees or other features to assist in concealment, the tactic of burning grass in patches large enough to accomodate vehicles has been employed with good results.

Where a sound is audible, distinctive, and locatable, it is often possible to create similar sounds over a large area, thereby confusing the identity and location of the significant sound signature.

Table 5-3

DISGUISE TECHNIQUES

TECHNIQUE 1: ELIMINATION AND OBSCURATION OF IDENTITY CUES

The methods of hiding and blending are of limited usefulness to the camouflage of military materiel where it is necessary to defeat observation at close range. The perceptibility of an item/system is related to the real or imagined threat it poses to an observer. The elimination of characteristics in materiel and postures indicating threats to an enemy tend to lessen perceptibility; i.e., a weapon is feared but a truck is not. Removing or covering the characteristics which indicate that an item is still a weapon will make it appear to pose little threat.

Disguise can prevent the tracking of force structure without denying the force's presence. Disguise is used in conjunction with other operational techniques such as moving a force system by infiltration in lieu of convoy or by mixing several units at random in convoy.

EXAMPLES:

Tarpaulins placed over an item to which air bags, boxes, or other form altering means have been attached conceals the recognition cues which are associated with threats. Obscuration of the gun barrels of artillery or tanks, by use of camouflage materiel (nets, disrupters, etc.) will prevent or delay recognition of the weapon.

TECHNIQUE 2: INCORPORATION OF BACKGROUND CUES

This technique is related to the hiding and blending methods discussed previously; it differs because the act is to add items from the natural environment, thereby giving to the item/system cues which are characteristic of the innocuous background.

EXAMPLES:

Adding branches of foliage to a weapon can make it appear as a natural growth of brush.

Strategic placement of large rocks on, or boulders around the military item will effect a level of disguise in a rocky environment.

Table 5-3 (Contd)

DISGUISE TECHNIQUES

TECHNIQUE 3: INCORPORATION OF SECOND ITEM CUES

This technique involves changing the appearance of a military item to that of another man-made item. The appearance change is to that of a less threatening or less valuable item

EXAMPLES:

An item/system can be downgraded in appearance by incorporating cues of another military item/system. The term appearance is used here to describe cues recognizable by any of the human senses or inanimate sensor devices, e.g., the sound emitted by a mobile weapon can be damped or otherwise altered to duplicate the sound of a less threatening vehicle. Also, the radar cross section of a large, valuable item/system can be reduced (by selective placement of radar absorbing materials) to yield the cross section of a smaller, less valuable item/system.

An example of visual appearance downgrading is the alteration of a military vehicle to give it cues of a civilian vehicle. This technique could have particular application in an urban environment.

Table 5-3 (Contd)

DISGUISE TECHNIQUES

TECHNIQUE 4: MODIFICATION OF SPOOR AND ACTIVITY CUES

Mobility equipment items frequently leave a trail of environmental change, or deployment of certain kinds of equipment frequently presents a characteristic pattern. These resultant spoor and activity cues can be modified to deter identification of the specific equipments or activities.

EXAMPLES:

Deployment of certain weapons has historically taken a specific geometric form, e.g., tanks in a circle or artillery in a semicircle. Substituting an irregular geometry for these cues can delay the enemy's detection or identification of the weapons.

Trails left by tracked vehicles are distinguishable from those of wheeled vehicles. Modification of the trails by dragging devices, etc., can delay recognition of a tracked-vehicle trail.

A missile system, having fixed physical characteristics which require that each element of the firing battery be interconnected with cable of fixed length and have a clear path between elements for line-of-sight communications, exhibits a fixed ground pattern of deployment. This is usually reinforced by standard operating procedures which give quick reaction capabilities. These ground patterns are quickly learned by an enemy and greatly aid in recognition. A variable ground pattern of deployment will prevent this recognition.

Characteristic warm-up procedures or pre-firing activities can be modified to prevent recognition.

Table 5-4

DECOY TECHNIQUES

TECHNIQUE 1: CREATION OF FALSE SIGNALS

Some items of military equipment give off characteristic signals of an acoustic, seismic, or electromagnetic nature. Reconnaissance operations by unfriendly forces can utilize these signals to locate and identify friendly materiel. Creation of false signals, which the enemy accepts as valid, serve to draw attention from actual materiel, cause the enemy to consume additional energy or firepower, draw false conclusions about friendly force position or strength, and otherwise confuse or disrupt the enemy's operations.

EXAMPLE:

Certain missile launchers employ active radars, whose signals can be duplicated by a decoy transmitter. Enemy systems designed to detect or home-in on this signal will therefore be deceived. Some items of military equipment are vulnerable to detection by the heat energy they emit, and are vulnerable to attack by weapons employing thermal-infrared-seeking devices. Deployment of decoy thermal infrared sources will give false detection information to the enemy and will serve to distract or redirect the thermal-infrared-seeking devices.

TECHNIQUE 2: CREATION OF FALSE PART, ITEM, SYSTEM OR ACTIVITY THAT DUPLICATES MAJOR DETECTABLE IDENTITY CUES OF AN ARCHETYPE

Decoy objects are used to draw attention or enemy fire, thereby diluting the enemy's efforts to detect and destroy real items of equipment. The sophistication (degree of fidelity) required of decoys increases as a sensor sophistication increases; future decoys will require simulation of archetype signatures in the thermal infrared and radar spectral region, as well as in the visual region.

EXAMPLE:

A tank decoy can be equipped with recordings of the actual sounds of a mobile tank and its weapon reports, as well as radar reflective materials and thermal sources that simulate a real tank.

The Hawk missile launcher decoy simulates the geometry and visual appearance of a real launcher. Radar reflective materials are also incorporated that simulate the radar cross section of a real launcher, and a radar transmitter can be used which will simulate the battery's active radar system.

Table 5-4 (Contd)

DECOY TECHNIQUES

TECHNIQUE 3: CREATION OF ITEM CUES NOT RELATED TO AN ARCHETYPE

This decoy technique involves creating a cue (signal, emission, etc.) that is recognized as not naturally occurring and is therefore considered a possible threat.

EXAMPLES:

A camouflage screen, erected but covering no item of military value, will draw attention or firepower, or both, if placed so it can be discovered by the enemy. Saturating an area with "empty" screens can significantly confuse or distract the observers. Other examples of this decoy technique are: mirrors or flashlights used to direct light toward enemy observers; a corner reflector or broad-band radar transmitter hidden among natural surroundings; acoustic recordings of mobile equipment passing through a forest, a seismic wave generator hidden behind natural obstructions.

5.7 EQUIPMENT SIGNATURE TABLES

Tables 5-5 through 5-13 indicate a variety of camouflage problems which exist for items/systems of Army equipment. For each significant event or mode of operation of the equipment on the battlefield, a description of a characteristic signature and its source is listed. The spectral region of surveillance and target acquisition systems capable of detecting and recording these signatures are indicated along with possible camouflage techniques to reduce these same signatures. Signature importance is not indicated in these tables since that question is answered on an individual basis by the threat assessment, Section 3.

These tables serve two purposes. They aid the developer in considering all aspects of the perceptibility of his equipment to the enemy, and they also serve as an index to specific camouflage data sheets by indicating the spectral region of concern for each signature. The following key is used in the tables to signify the individual spectral regions. A discussion of the sensing systems operating in each of these regions is found in Section 3.

UV	Ultraviolet	EMP	Electromagnetic Pulse
V	Visual	M	Magnetic
NIR	Near Infrared	A	Acoustic, Sonic
TIR	Thermal Infrared	S	Seismic
R	Radar	C	Chemical
RF	Radio Frequency	O	Other

Table 5-5

CHARACTERISTIC SIGNATURES OF WEAPONS

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Projectile Launch, Rocket Launch	Muzzle Blast, Rocket Exhaust	Sound pulse	A	Silencer
		Propellant gas cloud	V, IR, C	Smoke, propellant chemistry change
		Dust cloud	V, TIR	Site preparation, smoke
	Muzzle Flash, Rocket Exhaust	Line-of-sight flash & atmospheric scattered flash, EM pulse	V, NIR, TIR, R, EMP	Flash hider, propellant chemistry change, daylight operation, Decoy Blast, Decoy Flash
	Weapon Recoil	Ground shock	S	
Projectile Flight	Projectile	Visible object	V	Low visibility coating
		Radar cross section	R	RAM, low RCS geometry
		Hot object	TIR	Low emissivity coating
	Supersonic Projectile	Flow noise	A	
	Projectile Impact	Flash, shock, blast	V, NIR, TIR, A,S	
Tactical Deployment	Tactical Configuration	Characteristic shape size, appearance and location	V, NIR, TIR, R	Natural concealment, low gloss coating, pattern painting, screen, smoke, chaff, disrupters, disguise, kit, decoys

Table 5-5 (Cont.)

CHARACTERISTIC SIGNATURES OF WEAPONS

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Tactical Deployment	Ground Pattern	Characteristic relationship with other objects	V, NIR, TIR, R	Variable employment doctrine, decoy
		Presence of engine generators	V, NIR, TIR, RF	(see Table 5-8 for engine generators)
		Presence of communication equipment	V, NIR, TIR, RF	(see Table 5-8 for communication equipment)
		Disturbed soil	V	Soil colorant, tone down materials
	Activity	Characteristic type, sequence, and relationship to other events	V, NIR, TIR	Avoid standardized activities
		Muzzle blast ground pattern	V	Site preparation
		Hot barrel and other equipment parts	TIR	IR shields, insulation, cooling low emissivity coatings, reposition hot spots
		Power supply, noise heat	A, TIR	Mufflers, frequency modification IR shield, insulation, cooling, low emissivity coating, reposition hot spot
		Effluents	V, TIR, C	Cool exhaust, redirected exhaust low visibility, exhaust, smoke

Table 5-5 (Cont.)

CHARACTERISTIC SIGNATURES OF WEAPONS

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Tactical Deployment	Activity	RF emission	RF	ECCM
		Litter	V	Discipline, tone down packing materials
	Insolation Dependent Temperature Changes	Thermal contrast between equipment and background	TIR	
Road March	Mobile Configuration	Characteristic shape, size and appearance	V, NIR, TIR	Low gloss coating, pattern painting, covered in transit, disguise kit, disrupters
	March Order	Characteristic convoy arrangement	V, NIR, TIR	Avoid standardized configuration, ubiquitous vehicles
	Route	Route options restrained by terrain trafficability	V, NIR, TIR, R	Increase weapon mobility
		Tire, track marks on ground	V	Discipline, soil colorants
	Motion	Dust cloud	V, TIR	Dust control device
		Ground impact	S	Seismic wave generator quiet tracks
		Equipment noise	A	Secure equipment, sound control, frequency modification

Table 5-5 (Cont.)

CHARACTERISTIC SIGNATURES OF WEAPONS

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Road March	Motion	Movement	V, TIR, R	Smoke, chaff, natural terrain masking
		Direction	V, TIR, R	Smoke, chaff, natural terrain masking
		Large metal mass	M	
Rear Area Storage	Storage Configuration	Characteristic shape size, appearance, location, and relationship with other objects	V, TIR, R	Covered storage, natural concealment, disguise kit, low gloss coating, pattern painting, RAM, low RCS geometry
Resupply	Logistic System	Fixed supply points	V, TIR	Variable resupply system, concealed supply point
		Characteristic resupply vehicle	V, TIR	Non-unique vehicle, disguise kit
	Activity	Activity	V, TIR	Covered work area, screens
		Repair tools	V, TIR	Covered work area, screens, disguise kit
		Noise	A	Mufflers

Table 5-6

CHARACTERISTIC SIGNATURES OF VEHICLES

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Moving	Mobile Configuration	Characteristic shape, size, and appearance	V, NIR, TIR	Low gloss coating, pattern painting, disguise kit, disrupters
	March Order	Characteristic convoy arrangement	V, NIR, TIR	Avoid standardized configuration, ubiquitous vehicles
	Route	Route options restrained by terrain trafficability	V, NIR, TIR, R	Increase vehicle mobility
		Tire, track marks on ground	V	Discipline, soil colorants
	Motion	Dust cloud	V, TIR	Dust control device
		Ground impact	S	Seismic wave generator, quiet tracks
		Equipment noise	A	Secure equipment, sound control, frequency modification
		Movement	V, TIR, R	Smoke, chaff, natural terrain masking
		Direction	V, TIR, R	Smoke, chaff, natural terrain masking
		Large metal mass	M	

Table 5-6 (Cont.)

CHARACTERISTIC SIGNATURES OF VEHICLES

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Moving	Motion	Power supply, noise	A	Mufflers, frequency modification
		Power supply, heat	NIR, TIR	IR shield, insulation, cooling, low emissivity coating, reposition hot spots
		Power supply, effluent	V, C, NIR, TIR	Cool exhaust, redirected exhaust, low visibility exhaust, smoke
		Power supply, RF emission	RF	ECCM
		Hot wheels, tracks	TIR	IR shields
		Hot vehicle parts	TIR	IR shields, low emissivity, coatings, insulation, cooling, reposition hot spots
Combat	Firing Weapons	(SEE WEAPONS, PROJECTILE LAUNCH)		
	Active Target	IR searchlight	NIR	Restricted use, pulse mode
	Acquisition Devices	Laser rangefinder	V, NIR	Restricted use, pulse mode
	Enemy Target Acquisition System	Laser rangefinder	V, NIR, TIR	Low emissivity, difusc coating, mirrors, threat monitor
		Laser target designator	V, NIR, TIR	Same as above

Table 5-6 (Cont.)

CHARACTERISTIC SIGNATURES OF VEHICLES

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Stationary	Tactical Configuration	Characteristic shape size and appearance	V, TIR, R	Natural concealment, low gloss coating, pattern painting, screens, smoke, chaff, disrupters, disguise kit, decoys, RAM, low RCS geometry, shadow control, windshield glare control
	Ground Pattern	Characteristic relationship with other objects	V, TIR, R	Change deployment doctrine, soil colorants, tone down materials
	Activity	Characteristic type sequence and relationship to other events	V	Avoid standardized activities
	Insolation Dependent Temperature Changes	Thermal contrast between equipment and background	TIR	
Resupply	Logistic System	Fixed supply points	V, TIR	Variable resupply system, concealed supply point
		Characteristic resupply vehicle	V, TIR	Non-unique vehicle, disguise kit
Maintenance	Activity	Noise	A	Mufflers
		Activity	V, TIR	Covered work area, screens
		Repair tools	V	Covered work area, screens, disguise kit
Rear Area Storage	Storage Configuration	Characteristic shape, size appearance, location, and relationship with other objects	V, TIR, R	Covered storage, natural concealment, screens, disguise kit, low gloss coatings, pattern painting, RAM, low RCS geometry

Table 5-7

CHARACTERISTIC SIGNATURES OF AIRCRAFT

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Tactical Flying	Flight Noise	Engine noise	A	NOE, mufflers
		Blade noise	A	NOE, quiet blades
	Flying Configuration	Characteristic shape, size, and appearance	V, TIR, R	NOE, smoke, chaff, RAM, low RCS geometry, pattern paint, low gloss paint, low contrast with background
		Sun glint	V, NIR	Low emissivity coating, canopy redesign
		Engine exhaust plume	V, C, NIR, TIR	Low emission engine, fuel chemistry change
		Engine RF emissions	RF	ECCM
		Hot spots	TIR	IR shield, cooling, low emissivity coating, insulation, reposition hot spots
Weapons Firing	(SEE WEAPONS, PROJECTILE LAUNCH)			
Parked, Downed	Ground Configuration	Characteristic shape size, appearance and relation with other objects	V, TIR, R	Covered storage, natural concealment, screens, smoke, chaff, decoy
Resupply	(SEE WEAPONS, RESUPPLY)			
Maintenance	(SEE WEAPONS, MAINTENANCE)			
Rear Area Storage	(SEE WEAPONS, REAR AREA STORAGE)			

Table 5-8

CHARACTERISTIC SIGNATURES OF ENGINE GENERATOR SETS

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Tactical Employment	Item Configuration	Characteristic shape, size, appearance	V, TIR	Natural concealment, low gloss coating, pattern painting, screens, disguise kit
		Engine noise	A	(See Weapons - power supply)
		Engine heat	NIR, TIR	(See Weapons - power supply)
		Engine effluents	V, TIR, C	(See Weapons - power supply)
		Engine RF emissions	RF	(See Weapons - power supply)
		Generator RF emissions	RF	ECCM
	Insolation Dependent Temperature Changes	Thermal contrast between equipment and background	TIR	
Refuel	Logistic System	Characteristic refuel vehicle or procedure	V	Non-unique vehicle, disguise kit, concealed refuel procedure
Rear Area Storage	Item Configuration	Characteristic shape, size, and appearance	V, TIR	Covered storage, natural concealment, low gloss coating, pattern painting, screens, disguise kit.
Transport	Item Configuration	Characteristic shape, size, and appearance	V, NIR, TIR, R	Low gloss coating, pattern painting, covered in transit, disguise kit, transported by ubiquitous vehicle.

Table 5-9

CHARACTERISTIC SIGNATURES OF COMMUNICATION EQUIPMENT

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Tactical Employment	System Configuration	Characteristic shape, size, appearance, location, and relationship with other objects	V, TIR	Natural concealment, low gloss coating, pattern painting, screen, disrupters, disguise kit, ubiquitous container
		Presence of antennae	V	Lower antannae, slot antennae
		Presence of engine generator	V, TIR, A	(See Engine Generator Set)
	Activity	Electronic emissions	RF	ECCM
		Characteristic traffic	V, A	Natural concealment, discipline, concealed traffic routes
		Equipment hot spots	TIR	IR shields, insulation, cooling, low emissivity coatings, reposition hot spots
Transport	Item Configuration	Characteristic shape, size and appearance	V, TIR, R	Low gloss coating, pattern painting, covered in transit, disguise kit, transport by ubiquitous vehicle
Rear Area Storage	Item Configuration	Characteristic shape, size, appearance, location, and relationship with other objects	V, TIR	Covered storage, natural concealment, screens, disguise kit, low gloss coating, pattern painting, ubiquitous container

Table 5-10

CHARACTERISTIC SIGNATURES OF FIELD RANGES, HEATERS

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Tactical Employment	System Configuration	Characteristic shape, size and appearance	V, TIR	Natural concealment, low gloss coating, pattern painting, screens, disguise kit
	System Operation	Exhaust plume	V, TIR, C	Dilute with cool air, redirect exhaust, increase combustion efficiency
		Hot system components	NIR, TIR	IR shields, insulation, low emissivity coatings, cooling, reposition hot spots
		Periodic concentration of personnel	V	Discipline, concealed site
		Equipment noise	A	Quiet mess gear
		Equipment shine	V	Low gloss mess gear
		Litter	V	Discipline
Resupply	Logistic System	Characteristic resupply vehicle or procedure	V, C	Non-unique vehicle, disguise kit, non-unique procedure, concealed supply points
Transport	Item Configuration	Characteristic shape, size, and appearance	V, TIR, R	Low gloss coating, pattern painting, covered in transit, disguise kit, transported by ubiquitous vehicle
Rear Area Storage	Item Configuration	Characteristic shape, size, and appearance	V, TIR	Covered storage, natural concealment, screens, disguise kit, low gloss coating, pattern paint

Table 5-11

CHARACTERISTIC SIGNATURES OF TACTICAL POL EQUIPMENT

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Construction	Construction Activity		V	Colorant for disturbed soil
Operational	Bulk Storage Container	Characteristic shape, size, appearance, location, and relationship with other objects	V, TIR	Concealed area, low gloss surface pattern paint, screens, disrupters, disguise kit
		Thermal lag	TIR	
	Pipe Lines	Characteristic shape, size, appearance, location, and relationship and other objects	V, TIR	Route under natural concealment low gloss coating, screens, disrupters, pipeline covers
		Thermal lag	TIR	
	Tank Trucks	Activity, presense	V, TIR	Locate terminal under natural concealment, discipline
	Engine, Pump, Filter	Characteristic shape, size and appearance	V, TIR	
		Noise	A	(See Weapons - Power Supply
		Heat	NIR, TIR	(See Weapons - Power Supply)
		Effluents	V, TIR, C	(See Weapons - Power Supply)
		RF emissions	RF	(See Weapons - Power Supply)

Table 5-12

(U) CHARACTERISTIC SIGNATURES OF SHELTERS, TENTAGE, AND CONTAINERS

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Tactical Employment	Tactical Configuration	Characteristic shape, size, appearance, location, and relationship with other objects	V, TIR, R	Natural concealment, low gloss coatings, pattern painting, screens, disrupters, disguise kit, ubiquitous design, RAM, low RCS geometry
	Specialized Activities Associated with the Contents	Noise source	A	(See Weapons - Power Supply
		Heat source	TIR	(See Weapons - Power Supply
		RF source	RF	ECCM
		Light source	V	Discipline, shutters, filters
		Litter source	V	Discipline
		Characteristic traffic	V	Discipline, concealed area
Transport	Item Configuration	Characteristic shape, size, and appearance	V, TIR, R	Low gloss coating, pattern painting, covered in transit, disguise kit, ubiquitour design
Rear Area Storage	Item Configuration	Characteristic shape, size and appearance	V, TIR R	Above plus natural concealment, covered storage, screens, RAM, low RCS geometry

Table 5-13

CHARACTERISTIC SIGNATURES OF MINES

System Mode or Event	Signature Source	Signature Description	Spectral Region	Camouflage
Minefield	Emplaced Configuration	Characteristic shape, size, and appearance	V, TIR	Bury, hide, conceal, disguise, decoy
	Mine Material Different From Soil	Altered ground temperature distribution	TIR	Match characteristic
		Altered ground electrical characteristic	RF	Match characteristic
		Altered ground magnetic characteristic	M	Match characteristic
		Altered ground mass characteristic		
Transport	Packaged Configuration	Characteristic shape, size and appearance	V, TIR	Low gloss coating, covered in transit, ubiquitous container, disguise kit
Rear Area Storage	Packaged Configuration	Characteristic shape, size, and appearance	V, TIR	Low gloss coating, covered storage, natural concealment, disguise kit, ubiquitour container

5.8 CAMOUFLAGE DATA SHEETS

Specific information on camouflage technology has been collected onto data sheets in this Section. Table 5-14 is an index to these data sheets which indicates the spectral region in which the technology is effective. This index may be searched to locate available information on camouflage associated with a specific spectral region.

The data sheet numbering system indicates whether this sheet contains information on Techniques (Series 1000), Materiel (Series 2000), or Materials (Series 3000). The technique series is subdivided into Hiding (100), Blending (200), Disguising (300), and Decoying (400). The final two numerals indicate the sequence of the data sheets within each series.

Camouflage technology is classified on these sheets by technique, materiel, and material. Technique is a procedure to effect camouflage; camouflage materiel is a completed camouflage line item; and camouflage material is something to be incorporated into materiel through a technique. An example of a camouflage technique is the general procedure of using local, naturally occuring materials to effect camouflage (see data sheet 1208); the technique description does not attempt an exhaustive classification of local materials, but does convey a broad understanding of the procedure. A camouflage materiel is a ready-to-use item, such as the lightweight screening system (see data sheet 2000). A camouflage material needs to be manipulated by the user, e.g., cutting and forming radar absorbing material, RAM (see data sheets 3000-3005), in order to achieve the desired effect.

Recent advances in camouflage (e.g., modular, lightweight screening systems) are causing some materiel to become obsolete. A description of these materiels, some of which may persist in the military inventories, can be found in publications such as "Miscellaneous Paper M-76-21, Camouflage Materials for Fixed-Installation Concealment," Mobility and Environmental Control Laboratory, U. S. Army Engineers Waterways Experiment Station (AD A033933).

Table 5-14

CAMOUFLAGE DATA SHEET INDEX

Data Sheet Number	Title	Effective Spectral Region
1100	Mirrored Surfaces to Gain Concealment Through Reflecting the Surround to the Observer	V, NIR, R
1101*	(S) Optical Augmentation Protection	UV, V, NIR
1102	Reflectivity Reduction for Laser Susceptibility Control	UV, V, IR
1200	Redirection of Radiant Energy from Objects	TIR
1201	Shadow Elimination by Artificial Lighting or Positioning to Use Natural Shadows.	UV, V, NIR
1202	Thermal Shielding	TIR
1203	Radar Countermeasure Design Configurations	R
1204	Control of Surface Scattering (Texturing)	UV, V, NIR
1205	Mirrored Surfaces for Camouflage Against Searchlight Type Illumination	V, R
1206	Thermal Radiation Control by Transpiration Cooling	TIR
1207	Control of Exhaust Gas Temperatures by Mixing with Heat Absorbing Liquids or Gases	TIR
1208	Camouflage Using Local Materials	UV, V, NIR
1209	Camouflage Pattern Painting	UV, V, NIR, TIR
1210	Camouflage Disrupters	UV, V, NIR, TIR
1211	Camouflage Hydroplanting	V, NIR
1300*	(C) Environmentally Activated Surface Disguise	V
1400*	(S) Laser Decoys	UV, V, NIR
1401*	(S) IR Decoy Systems	TIR
1402	Decoy Objects	UV, V, NIR, TIR, R, A, I, U, S, C, M
2000	Camouflage Screens (Nets)	UV, V, NIR, R
2001	Smoke Screens	UV, V, NIR
2002	Camouflage Foliage Brackets and Spring Clips	V, UV, NIR
2003	Camouflage Helicopter Canopy Glare Covers	UV, V, NIR, TIR
3000	Radar Absorbing Material-Flat Plate, Resonant	R
3001	Radar Absorbing Material-Flat Plate, Broadband, Graded	R
3002	Radar Absorbing Material-Ferrite	R
3003	Radar Absorbing Material-Low Density	R
3004	Radar Absorbing Material-Circuit Analog	R
3005	Radar Absorbing Material-Geometric Transition	R
3006	Camouflage Paint for Pattern Painting	V, NIR
3007	Paint, Arctic, Camouflage, Removable MIL-P-52905	UV, V, NIR
3008	Paint, Camouflage Forest Green	V, NIR
3009	Solar and Heat Reflecting Camouflage Paint	V, NIR, TIR
3010	Low Reflective Acrylic Lacquer, MIL-L-46159	V, NIR
3011	Camouflage Cloth	UV, V, NIR, TIR, R
3012	Urethane Foam	V, NIR, TIR

*Refer to SECRET Annex

TITLE	DATA SHEET 1100
MIRRORED SURFACES TO GAIN CONCEALMENT THROUGH REFLECTING THE SURROUND TO THE OBSERVER	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To cause an observer to see only what is reflected in the mirror- a part of a local terrain.

POTENTIAL APPLICATION:

To static items in which the observation direction is restricted and well defined.

DESCRIPTION:

This technique exists in two forms. The first is the use of a mirror or mirrored sheeting placed between the item to be concealed and a potential observer (sensor). It is set at an angle which does not reflect bright sky and sun and with care to either avoid straight mirror edges or obscure them. The observer will see only the terrain reflected in the mirror and, since it will generally conform to the general surroundings in contrast, the installation will have a high probability of remaining undetected. The item itself is hidden behind the mirror.

The second form involves mirroring the item surface itself where potential observation angles are such that only the surrounding terrain will be seen. Curved surfaces will distort the reflected surround and not produce suitable reflections.

In many cases, the viewing of objects from the air and at long range will not greatly reduce the effectiveness of the technique. Applied to radar frequencies, a mirror can be made of open mesh wire screen which is optically transparent. Such screens may be useful against ground radars and shield activity from MTI radars.

EXPERIENCE:

Both plastic sheet mirrors in a window blind configuration and as applied directly to equipment have been experimented with over a considerable time. The MASSTER program evaluated the use of the window blind type in recent years and found them useful in limited circumstances. Experiments with missile models have also indicated good concealment potential under special circumstances.

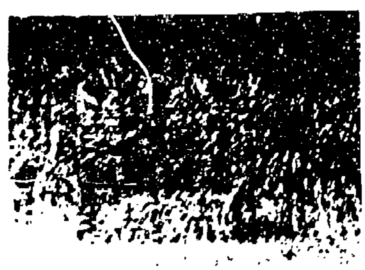
TITLE	DATA SHEET 1100
MIRRORED SURFACES TO GAIN CONCEALMENT THROUGH REFLECTING THE SURROUND TO THE OBSERVER	PAGE 2 OF 2

OTHER CONSIDERATIONS:

Optical mirrors are effective only if their surfaces are kept relatively clean. They are easily damaged and present a continuing maintenance problem. The technique is very old and formed the basis for magic illusions but whereas the magician has control of the situation the same cannot be said for military use. Its use in the radar area seems most appropriate. It is restricted in application but is highly effective in those instances where the combination of factors is favorable. This technique is also effective against thermal viewers.

REFERENCES:

1. Technical note No. 73-03, Camouflage by Reflectance of the Natural Terrain, August 1972, U. S. Army Land Warfare Laboratory, Aberdeen Proving Ground, Maryland 21005. AD 908941L.



TITLE REFLECTIVITY REDUCTION FOR LASER SUSCEPTIBILITY CONTROL	DATA SHEET 1102 PAGE 1 OF 1

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To reduce the effectiveness of laser designators and rangers against materiel.

POTENTIAL APPLICATION:

For use with tanks, armored personnel carriers, etc.

DESCRIPTION:

It is possible to apply coatings to materiel which will substantially reduce the optical return received by laser systems such as designators and rangers; the threat cannot be eliminated but it can be reduced.

Changing the diffuse reflectivity from 10% to 2% is probably achievable and would reduce the effective range of an attacking system by approximately a factor of two. Because of the high cost of this technique, it would only be used on expensive systems.

EXPERIENCE:

The specially treated surface is prone to the accumulation of dirt or moisture which negates the effect.

TITLE	DATA SHEET 1200
REDIRECTION OF RADIANT ENERGY FROM OBJECTS	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To deny detection by thermal infrared sensors by reducing the apparent temperature contrast of an item with its background.

POTENTIAL APPLICATION:

To items or item parts that permit the use of a standoff plastic sheeting between the item or part and the expected sensor position or path.

DESCRIPTION:

Radiant energy emitted from items or parts may be directed away from the field of view of a potential sensor by employing a faceted (prismatic) sheet of material possessing the proper refractive index and transparency for the wavelengths of energy concern (Figure 1). As illustrated in the sketch (Figure 2), a sensor has a limited field of view. By redirecting the radiation emitted from the surface through refraction in the prismatic sheeting, a large portion of the radiation can be denied to the sensor field of view. The surface behind the screen will, therefore, appear less warm than it would otherwise because the thermal energy will be redirected by the screen, not absorbed.

EXPERIENCE:

Sheeting has been produced and used to experimentally camouflage a generator--a particularly hot target. The success against an airborne IR sensor was demonstrated for a carefully installed configuration.

OTHER CONSIDERATIONS:

The use of this technique can be justified only by careful study by the user relative to the specific observation susceptibility of his item/system. The sheet material is bulky and heavy and should be used only for special installations.

TITLE	DATA SHEET 1200
REDIRECTION OF RADIANT ENERGY FROM OBJECTS	PAGE 2 OF 2

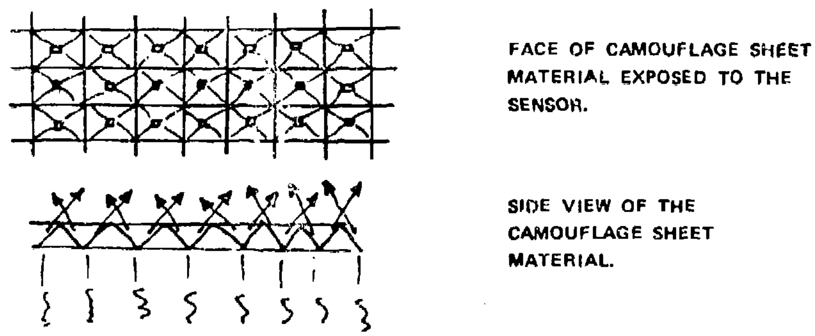


Figure 1

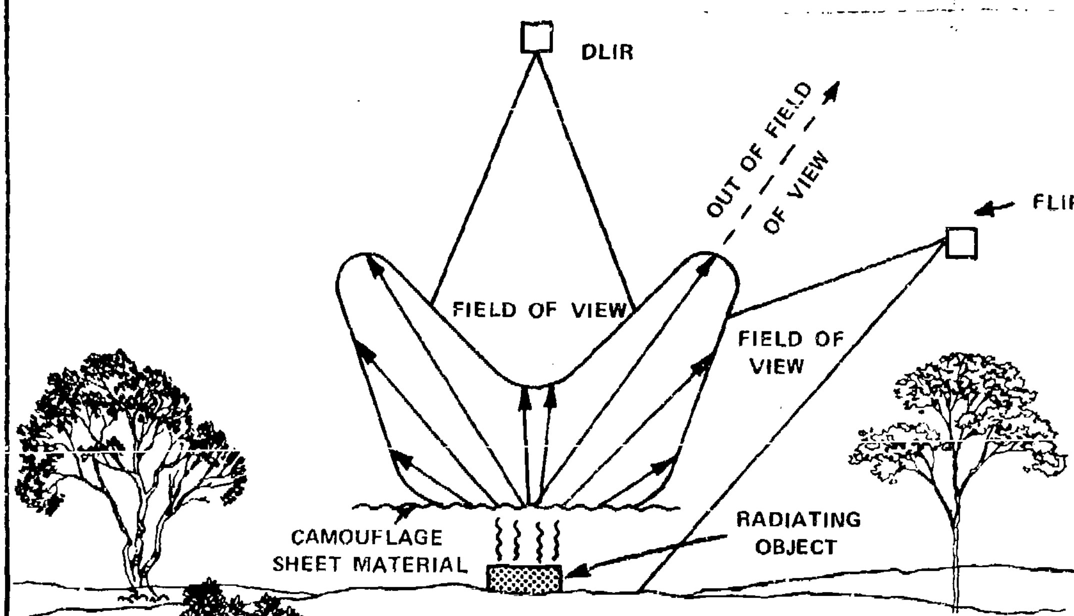


Figure 2

TITLE SHADOW ELIMINATION BY ARTIFICIAL LIGHTING OR POSITIONING TO USE NATURAL SHADOWS	DATA SHEET 1201
	PAGE 1 OF 4

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To remove a major source of identity cue creation and contrast by which items are detected and identified.

POTENTIAL APPLICATION:

To target items of a critical nature not subject to other camouflage techniques because of configuration requirements.

DESCRIPTION:

A primary source of contrast and outline formation by which objects are detected and identified results from shadows caused by directional illumination. Shadows to be considered are those which the item casts on the surrounding terrain or on itself.

Operational control can be effective where the item can be positioned within a secondary shadow of a wall or trees or next to foliage which protrudes through the shadow of the item thereby destroying the shadow outline and mass. This hiding of target item's shadow in the shadow of an innocuous object is depicted in the sketches of Figure 2. The only other means available is to illuminate the shadow by some means to the same luminance as that of the sunny side. Under very specific and controlled conditions this may be accomplished with mirrors to direct the sunlight (or other source) into the shadow. It must be remembered however, that the real world is constantly changing.

A second technique is to illuminate the shadow area with artificial lighting from electrical lamps and projectors tied to feedback control from sensors monitoring the environment. For those objects which in use will not cast a shadow on a background, incorporation of many small lamps on the shadowside can effectively reduce its detectability. Flat lighting with field stressed phosphorescent system (electro-luminescent) has application to marginal conditions but the intensity required for this and other artificial lighting techniques has limited the application to laboratory demonstrations only.

TITLE	DATA SHEET 1201
SHADOW ELIMINATION BY ARTIFICIAL LIGHTING OR POSITIONING TO USE NATURAL SHADOWS	PAGE 2 OF 4

EXPERIENCE:

During WWII the National Defense Research Council (NRDC) developed a contrast regulating system for attack aircraft by mounting a series of variable intensity lamps on the forward edge of the wings and fuselage. The intensity of the lamps were controlled by a rearward looking sensor that determined the luminosity of the sky to the rear of the aircraft. The system was code named "Yahudi" and permitted test aircraft to get quite close to their target before being visually detected. Experimental work has been done to illustrate the effectiveness of this technique but actual application has been rare.

Photochromic colorants have been applied which darken in sunlight and bleach in shade. These give marginal results but do reduce the contrast between the lighted and unlighted portions, especially under overcast conditions.

OTHER CONSIDERATIONS:

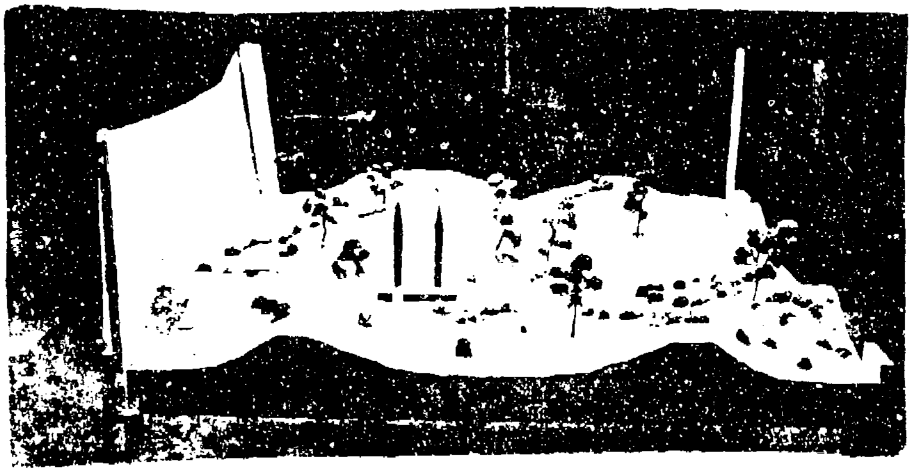
The incorporation of light (or other radiation) in shadows is a high cost technique and requires very careful control. These practical problems have so far prevented its use, even though a practical solution would have great effectiveness.

REFERENCES:

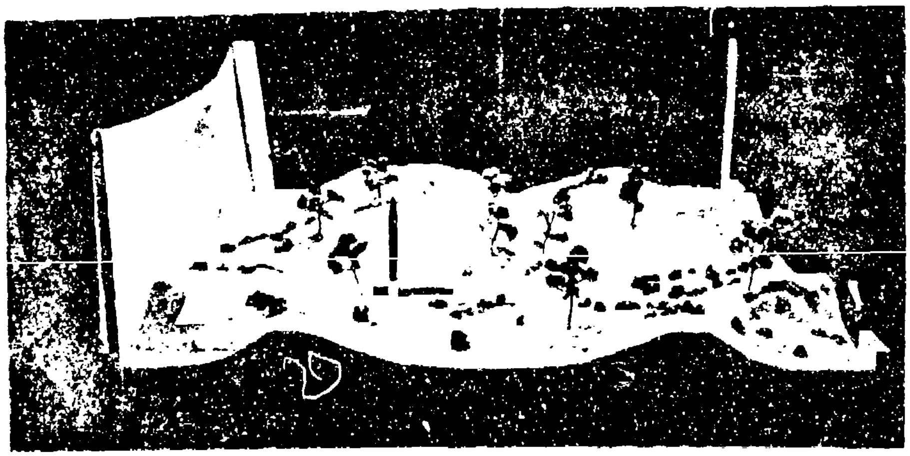
1. National Defense Research Council 16-3.

2. MERADCOM Camouflage and Topographic Laboratory Reference Center file C-505, The Feasibility of Concealing Targets Through the Use of Light.

TITLE SHADOW ELIMINATION BY ARTIFICIAL LIGHTING OR POSITIONING TO USE NATURAL SHADOWS	DATA SHEET 1201 PAGE 3 OF 4



TEST OBJECTS WITH DIFFUSED ILLUMINATION AND BACKLIGHTING



SAME TEST OBJECTS WITH ILLUMINATION PROJECTED ON RIGHT-HAND TEST OBJECT

Figure 1

TITLE	DATA SHEET 1201
SHADOW ELIMINATI BY ARTIFICIAL LIGHTING OR POSITIONING TO USE NATURAL SHADOW	PAGE 4 OF 4

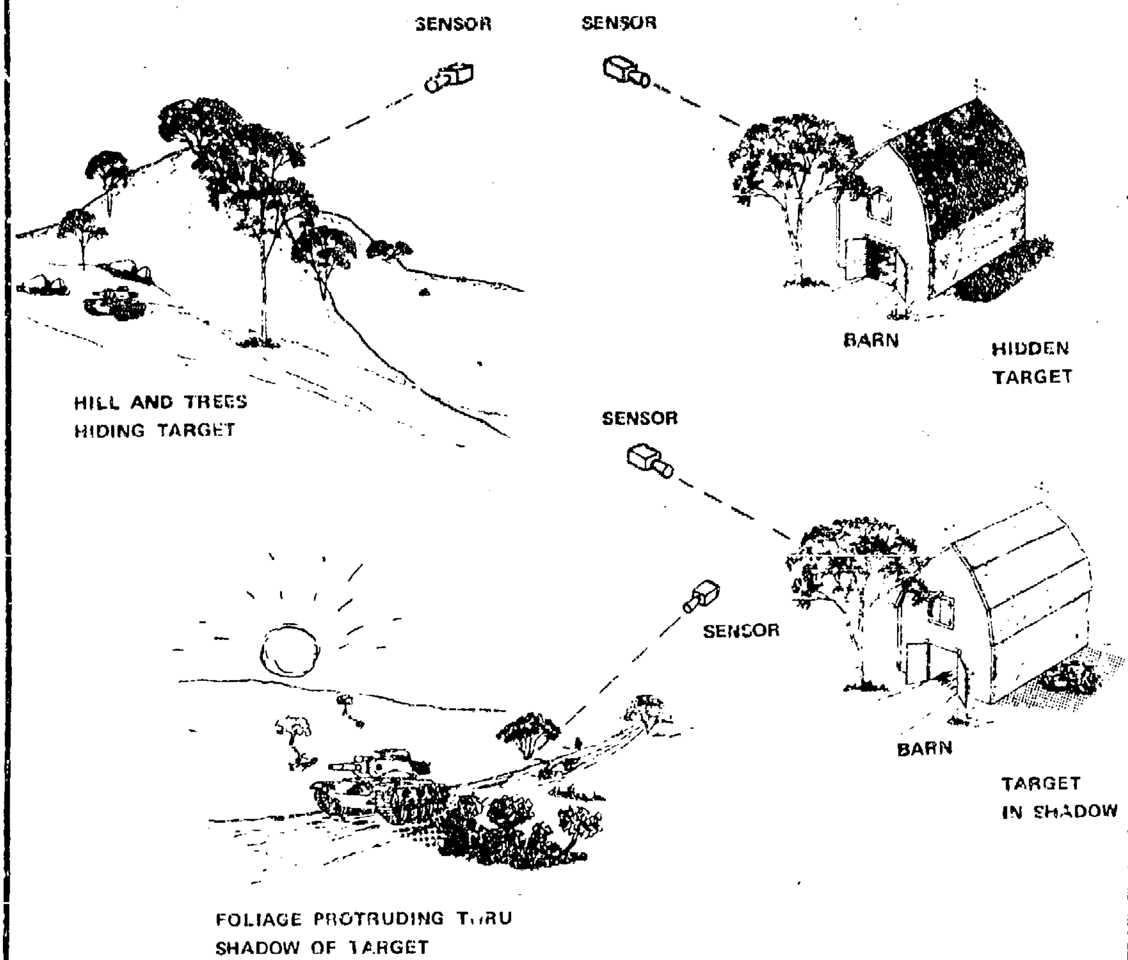


Figure 2

TITLE THERMAL SHIELDING	DATA SHEET 1202
	PAGE 1 OF 4

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To minimize detection of military objects by "thermal" sensors including terminal homing.

POTENTIAL APPLICATION:

Primarily to hot target parts which are external and not readily treatable by other means. Examples include engine exhausts, high temperature parts resulting from weapon firing, and high friction parts.

DESCRIPTION:

Remote sensing of thermal variations between targets and their backgrounds utilizes electromagnetic radiation, primarily in the spectral window regions of 3-to 5-micron and 8-to 14-micron wavelength. All surfaces above absolute zero temperature emit infrared radiation characteristic of the surfaces' temperature and emissivity. If the radiation emitted by the surface is sufficiently different from its surroundings, an image of that surface can be produced by electronic thermographic instruments which record the radiation in the direction of the sensor. Such instruments have detected temperature differences of as little as 0.2°C.* Blocking this radiation by interposing an opaque shield between the surface emitting the radiation and the sensor prevents the sensor from recording the surface radiation. The shield, however, is subject to observation in precisely the same fashion and over a period of time, depending on its physical nature, it will absorb the radiation from the surface to be hidden, increase in temperature, and in turn, be detectable. This can be minimized by:

(a) using a stand off distance between the shield and the object surface;

(b) using an inner shield surface of low emissivity to minimize energy transfer from the object surface;

(c) making the shield of a low thermal conductivity material; and

*Publication P-570, Eastman Kodak Company

(d) configuring the shield outer surface to have a greater area than the inner surface, have low emissivity in the 3-to 5-micron and 8-to 14-micron regions (while retaining good optical color and texture) and giving the shield a shape corresponding to the backgrounds in which the target is expected to function.

Shields will tend to be thin and low in mass which will quickly absorb or release energy to seek equilibrium with the air. Since the air is generally at a different temperature than the ground, or other background, the shields themselves are detectable and, therefore, must assume the nature of a disguise to reduce object perceptibility. An ideal shield would utilize a further means of temperature control through junction electronics (or other means) to vary the temperature of the shield and its emitted radiation to simulate the background using the feedback from a local monitor (sensor).

The use of forced air or other gas coolant between the object surface and the shield aids convective cooling of the shield.

For an integrated shield to be effective across the entire EM spectrum, it would require incorporating radar shielding techniques (see Radar Screening and RAM) and configurations, colors, and textures designed to defeat optical and near IR imaging sensors.

EXPERIENCE:

Thermal shielding has been successfully applied to aircraft engines to reduce the threat from thermal homing missiles and in the form of thermal modulators in an experimental camouflage system for a 45 KW diesel generator, and in the form of double screens for troop applied camouflage over static equipment and positions.

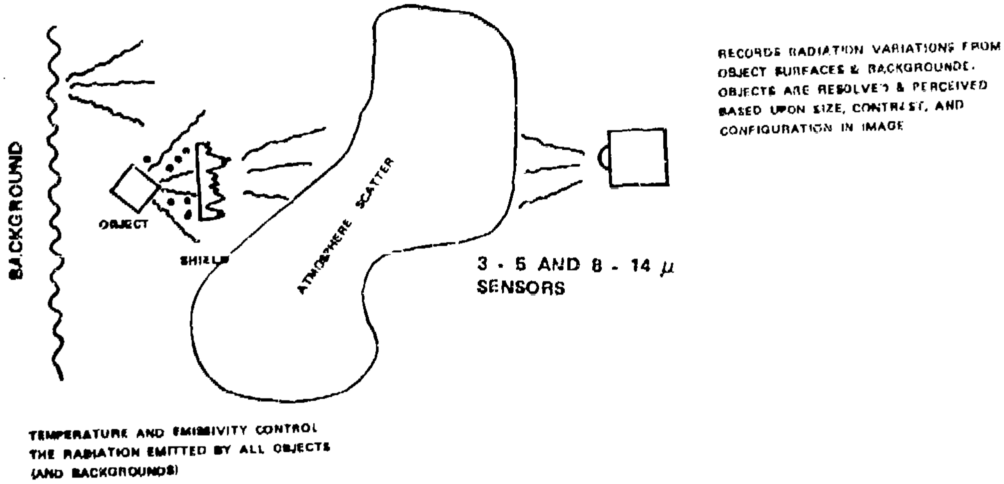
OTHER CONSIDERATIONS:

Shielding of very hot and otherwise untreatable portions of targets is the best application of this technique. Application to the whole target is less successful and interferes with access to the equipment.

Whole object camouflage by individual shields has low success probability on targets which tend to exceed background temperatures all over.

TITLE	DATA SHEET 1202
THERMAL SHIELDING	PAGE 3 OF 4

Selective applied shielding can be very effective in blocking highly detectable radiation to a sensor; especially to defeat a homing device using the 3-5 and 8-14 micron windows.



TITLE	DATA SHEET 1202
THERMAL SHIELDING	PAGE 4 OF 4

Selective applied shielding can be very effective in blocking highly detectable radiation to a sensor; especially to defeat a homing device using the 3-5 and 8-14 micron windows.

REFERENCES:

1. Final Report, Contract DAAK02-72-C-0286, Multispectral Camouflage of Four Army Vehicles and Two Generators ADC 004133L.

2. Final Report, Contract DAAK02-72-C-0286, Multispectral Camouflage for Generator ADC 000390L.

3. Final Report, Contract DAAK02-72-C-0286, Experimental Infrared Camouflage Canopy System AD 527013L.

4. Final Report, Contract DAAK02-67-C-0401, Experimental Infrared Material AD 391275.

5. Final Report, Contract DAAK02-70-C-0131, Experimental Research Prototype Infrared Camouflage Systems AD 519056L.

TITLE	DATA SHEET 1203
RADAR COUNTERMEASURE DESIGN CONFIGURATIONS	PAGE 1 OF 6

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To provide guidance to equipment developers on configurations to be avoided and those to use for maximum camouflage effectiveness in concealing from radar, by reducing the radar cross section of the equipment.

POTENTIAL APPLICATION:

Military hardware item/systems.

DESCRIPTION:

Design configurations to be avoided include the following:

1. Rounded geometries which always provide a direct (90^o) incident face at any illumination angle.

2. Normal incident faces between the +20^o and +40^o elevation angles associated with airborne platforms.

3. All 90^o (corner reflector) geometries. Any surface oriented 90^o from the normal ground plane or an adjacent surface creates an orthogonal corner reflector situation which will always reflect energy back to the threat Radar.

4. Energy entrapment cavities and major acute angle configurations. Cavities formed by structural configuration, large viewing ports, searchlights, etc., form critical energy "getters" which yield a concentrated return.

Design configurations to be incorporated where practical include the following:

1. The use of nonmetallics and nonwater-absorbing materials for protruding structures.

2. Shape, reshape, or cover critical structures or cavities with wire screening or other radar-opaque materials, so that they meet the above geometric requirements.

3. Consider the use of radar-attenuating coatings for otherwise inflexible design configurations.

TITLE RADAR COUNTERMEASURE DESIGN CONFIGURATIONS	DATA SHEET 1203 PAGE 2 OF 6

EXPERIENCE:

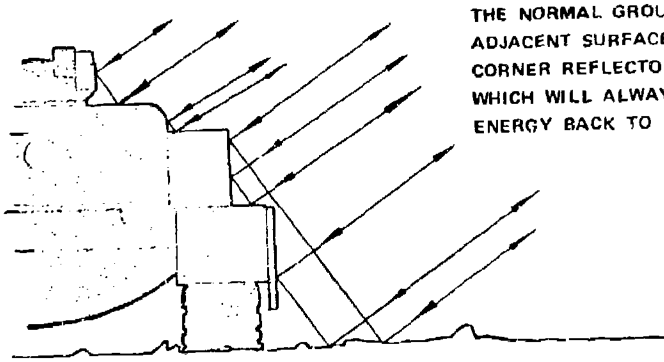
These design "do's and don'ts result from the examination of many equipment types employing the Radar Model Range at MERADCOM together with correlative field tests from extensive experience with aerospace studies at AFAL, et al.

OTHER CONSIDERATIONS:

The basis for these tips is the examination of the detailed structural configurations which, collectively, produce a weapon systems radar cross section (RCS).

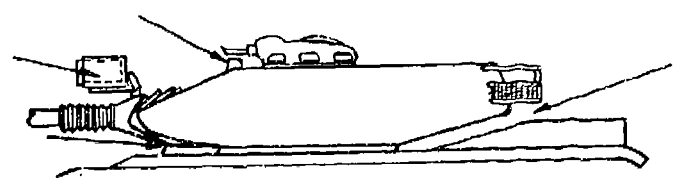
These tips are primarily effective for equipment in a static mode. Moving target indicator (MTI) radar effectiveness will only be reduced to some extent but not defeated.

AVOID ALL 90° (CORNER REFLECTOR) GEOMETRIES:

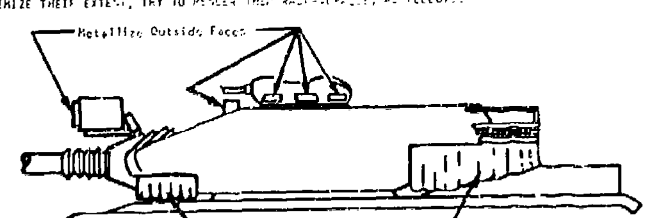


ANY SURFACE ORIENTED 90° FROM THE NORMAL GROUND PLANE OR AN ADJACENT SURFACE CREATES A CORNER REFLECTOR SITUATION WHICH WILL ALWAYS REFLECT ENERGY BACK TO THE THREAT RADAR

Avoid energy entrapment cavities or major acute angle configurations:



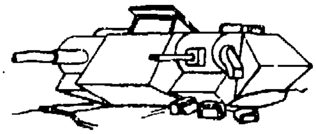
CAVITIES FORMED BY STRUCTURAL CONFIGURATIONS, LARGE [illegible], SEARCHLIGHTS, ETC, FORM CRITICAL ENERGY [illegible] WHICH YIELD A CONCENTRATED [illegible]. WHERE IT IS FUNCTIONALLY IMPOSSIBLE TO MINIMIZE THEIR EXTENT, TRY TO RENDER THEM [illegible], AS FOLLOWS:



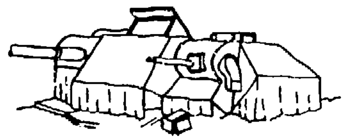
Attach Curtains of Metallized Cloth or Camouflage Material

TITLE	DATA SHEET 1203
RADAR COUNTERMEASURE DESIGN CONFIGURATIONS	PAGE 4 OF 6

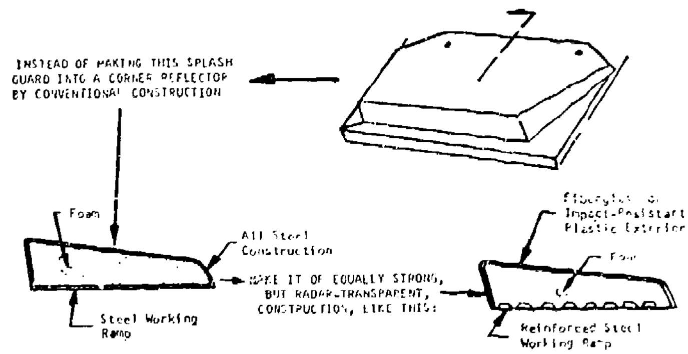
Avoid energy entrapment cavities or major acute angle configurations:



TYPICALLY, BY HANGING METALLIZED CURTAINS OR RADAR-SCATTERING CAMOUFLAGE AROUND THE TURRET, BALLISTICS OR OPERATIONAL PERFORMANCE WOULD NOT BE AFFECTED, SIMILARLY, "METALLIZING" THE NECESSARY VIEWPORTS WITH WIRE SCREENING OR THIN FILMS WOULD NOT IMPARE INTERNAL VISUAL PROPERTIES.

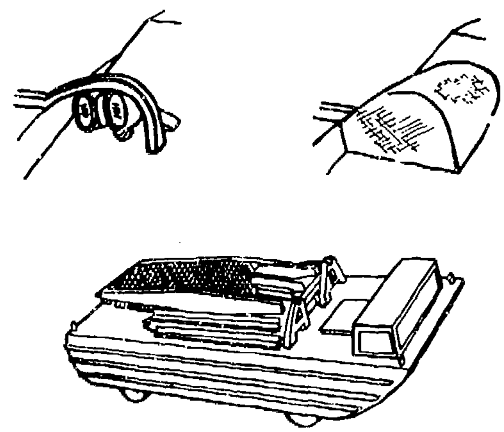


Where practical, use nonmetals for necessary protruding structures:

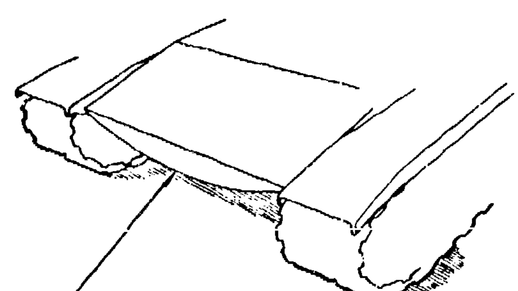


SIMILARILY, CONSIDER MAKING HAND-HOLDS, TIE-DOWNS, ETC. OF RADAR-TRANSPARENT FIBERGLASS OR PLASTIC CONSTRUCTION.

Where practical, reshape or cover critical areas with wire screening or other radar-opaque materials:

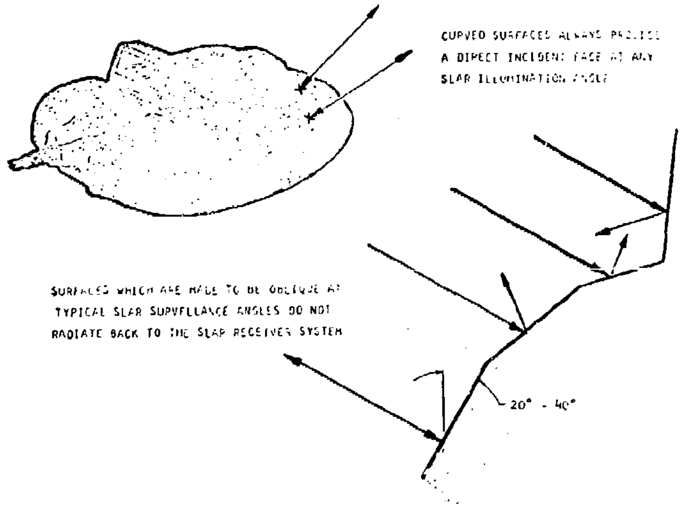


Consider the use of radar-attenuating coatings for otherwise inflexible design configurations.



1. Dare Technology, Inc., Scale OH-6A Helicopter Radar Cross-Section (RCS) and Microwave Imagery Studies (U), by M. H. Dawson and F. Rechlin, Report No. 74003, Contract DAAK02-72-C-0441, May 1974, Secret, AD 531928L.

Avoid rounded geometries and normal incident faces between approximately +20° and 40° from the vertical:



TITLE

CONTROL OF SURFACE SCATTERING (TEXTURING)

DATA SHEET 1204

PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To eliminate shine by controlling the specular reflection from surfaces.

POTENTIAL APPLICATION:

All exterior surfaces subject to observation.

DESCRIPTION:

Shiny surfaces exhibit specular reflection because nearly all the reflected energy is confined to a viewing angle dependent on the illumination angle. Matte surfaces, because they are textured, eliminate this "spike" of reflected energy by distributing it in a hemispherical pattern. Figure 1 depicts the relationship between illuminating angle and the relative angular intensity of reflected energy, for a shiny surface and for a matte surface, as measured by a goniophotometer.

Windshields, cooking pans and shiny metallic surfaces of vehicles are examples of surfaces that exhibit a high degree of specular reflection. This specular reflection is commonly detectable from long range and should be minimized: by building texture in a surface; permanently adding texture, e.g. by applying matte coatings; or by temporarily adding texture, e.g. covering the surface with camouflage cloth.

A smooth hot surface will emit thermal infrared radiation primarily in the direction perpendicular to the surface. Texturing the surface will hemispherically distribute the emissions; therefore, to a thermal sensor positioned normal to the flat surface, the surface will appear cooler if it is textured.

TITLE	DATA SHEET 1204
CONTROL OF SURFACE SCATTERING (TEXTURING)	PAGE 2 OF 2

EXPERIENCE:

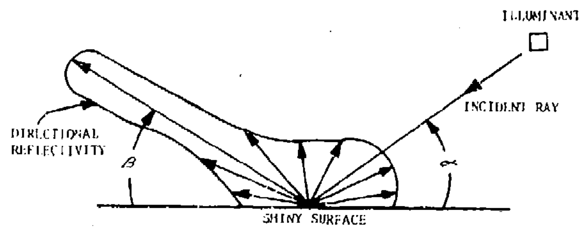
Most camouflage paints are formulated to yield a matte surface. Camouflage paints are currently applied to mobility equipment during manufacture.

Camouflage fabrics, e.g. those currently specified for cargo and vehicle covers, are produced with matte surfaces.

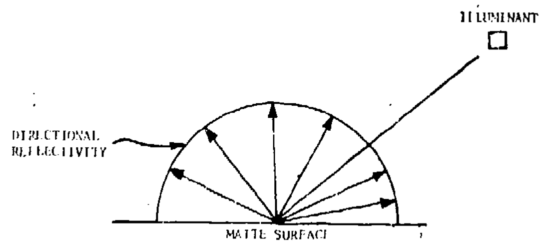
The camouflage cloth used in camouflage screen (LSS) fabrication possesses a matte surface.

OTHER CONSIDERATIONS:

Textured surfaces are prone to abrasion and collection of dirt and debris; maintenance procedures should include provisions for restoring textured surfaces.



$\propto = \beta$



TITLE	DATA SHEET 1205
MIRRORED SURFACES FOR CAMOUFLAGE AGAINST SEARCH-LIGHT TYPE ILLUMINATION	PAGE 1 OF 3

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To minimize detection of objects viewed against dark backgrounds (especially at night), when illuminated with point sources of radiation (search lights, radar, laser designators).

POTENTIAL APPLICATION:

To equipment subject to search light illumination and observation such as special night operating equipment.

DESCRIPTION:

It is normal to use a highly scattering (dull or textured) surface in the camouflage of items which are to be viewed in terrain backgrounds and are illuminated by sun, moon, or starlight. Some items are used only under particular circumstances in which this normal technique results in more perceptibility than if the surface were smooth and shiny. Sensor systems using searchlight methods to illuminate a target or area produce a geometry of illumination such that a redirection of the energy in directions other than back to the sensor is more effective than diffusing the amount of energy reflected from the whole object such as results from the use of dull paints. There will be points in the geometry where a high return from the mirrored surfaces will occur. These will become flashes on moving targets such as aircraft flying at night, but generally are so brief to be of little help to gunners.

EXPERIENCE:

This technique has been used in radar camouflage for many years to reduce apparent cross section by shaping the object to reflect most of the incident energy off into space or to be scattered in the terrain. It has been used optically with good success to conceal night flying aircraft subject to search light detection. In WWII this technique was code named BLACK-WIDOW-FINISH and consisted of a black lacquer gloss finish and a highly polished wax surface.

TITLE	DATA SHEET 1205
MIRRORED SURFACES FOR CAMOUFLAGE AGAINST SEARCH-LIGHT TYPE ILLUMINATION	PAGE 2 OF 3

OTHER CONSIDERATIONS:

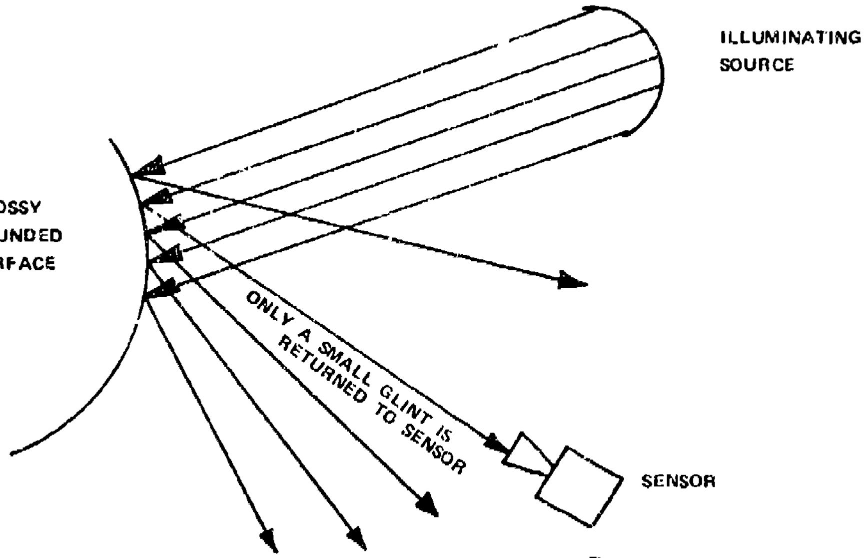
This technique is directed at a specific condition of observation and not a general condition to be encountered. Its use is, therefore, restricted to those situations. The user of this technique should be aware of its high perceptibility under other conditions. Such a finish is hard to maintain on field equipment and requires careful reconditioning for each use. Shiny black fabrics on which scattering patches are placed is effective for personnel in foliated backgrounds against sniperscope type IR viewing devices.

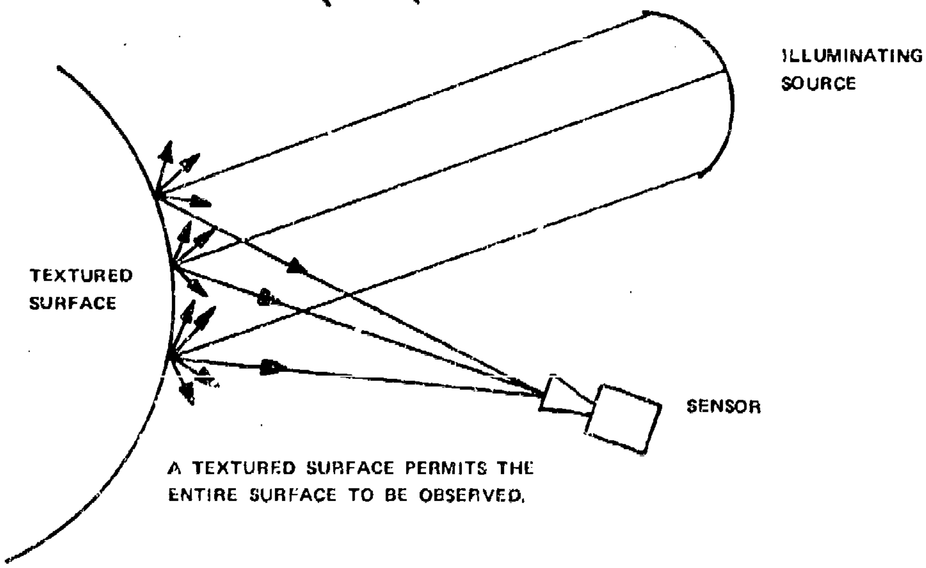
SEE DATA SHEETS: 1203

REFERENCES:

1. National Defense Research Council 16-3.

TITLE	DATA SHEET 1205
MIRRORED SURFACES FOR CAMOUFLAGE AGAINST SEARCH LIGHT TYPE ILLUMINATION	PAGE 3 OF 3





TITLE	DATA SHEET 1206
THERMAL RADIATION CONTROL BY TRANSPIRATION COOLING	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To control surface radiation through evaporative cooling achieved by transpiration to provide concealment from thermal infrared sensors.

POTENTIAL APPLICATION:

For cooling engine exhaust parts and other highly radiating surfaces where initial and upkeep costs together with intended employment in suitable environment are shown to be worth the result of increased survivability.

DESCRIPTION:

A porous surface coating can be applied to an object, with a reservoir of liquid supplied from behind, to achieve an even or variable flow of liquid to the surface. This liquid in turn evaporates, absorbing and convecting the thermal energy away by non-radiant means which otherwise would be contained in the object, raising its temperature and increasing its IR emission. In non-humid conditions water will usually be a suitable liquid: under other conditions, alcohol or other more volatile liquids may be required.

EXPERIENCE:

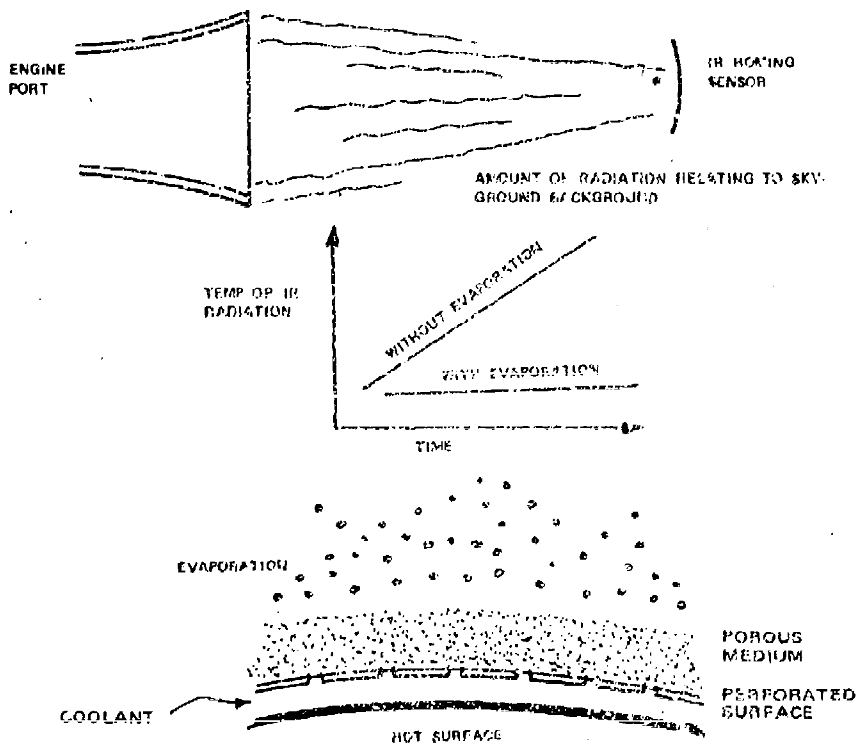
A porous coating has been experimentally applied to the inner surface of the exhaust nozzle of a jet engine to reduce its apparent temperature and IR radiation by producing a thin film of water at the surface to help defeat IR homing missiles. (Further cooling was accomplished by flowing incoming fuel around the nozzle, transferring some of the energy by convection.)

OTHER CONSIDERATIONS:

This is a sophisticated technique applicable only to critical items because of cost and complexity. It requires a renewable supply of liquid and there is danger in the use of volatile flammable liquids. It would normally be used only at critical times and not continuously.

TITLE	DATA SHEET 1206
THERMAL RADIATION CONTROL BY TRANSPIRATION COOLING	PAGE 2 OF 2

THERMAL RADIATION CONTROL THROUGH TRANSPIRATION



TITLE	DATA SHEET 1207
CONTROL OF EXHAUST GAS TEMPERATURES BY MIXING WITH HEAT ABSORBING LIQUIDS OR GASES	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To reduce thermal signatures and hot points in order to defeat thermal infrared sensors.

POTENTIAL APPLICATION:

All internal combustion engines.

DESCRIPTION:

Combustion products from internal combustion engines and normally exhausted through one or two pipes after passing through a sound reducer (muffler). These pipes are generally located to minimize crew exposure to dangerous gases and, in military vehicles, elevated to permit maximum fording capability. These pipes become very hot and are excellent homing points for thermal sensors.

In some cases the exhausts are located inside a grill (for physical protection) resulting in a large hot area. Mixing cold outside air and injecting volatile liquids to the exhaust close to the engine can cool the exhaust gases and thus reduce heating of the metal pipes, grills, etc., which would otherwise become intense radiators of infrared energy.

EXPERIENCE:

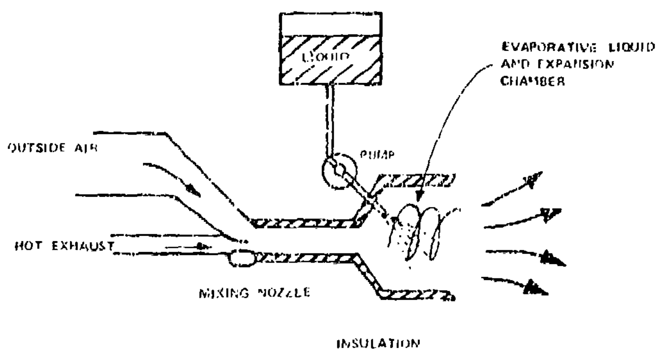
The M-48 tank was modified to draw in ambient air, and mix it with exhaust gases before being exhausted through insulated ports. A reduction in detectability range was achieved against the current sensors.

Aircraft engines have been equipped with liquid injection systems near the exhaust ports to reduce the exhaust temperatures through absorption of energy used in conversion of liquids to gases.

OTHER CONSIDERATIONS:

The use of air as a coolant, especially moist air, is effective and requires little additional energy expenditure by the power source of the item. The use of fluids injected into the exhaust, however, requires storage space, and resupply restricts its use to critical moments.

TITLE	DATA SHEET 1207
CONTROL OF EXHAUST GAS TEMPERATURES BY MIXING WITH HEAT ABSORBING LIQUIDS	PAGE 2 OF 2



CONTROL OF EXHAUST TEMPERATURES THROUGH MIXING WITH HEAT ABSORBING GASES OR FLUIDS

SEE DATA SHEETS: 1202, 1206

REFERENCES:

1. Final Report, Contract DAAG53-76-C-0099, "Thermal/Acoustic Generator Exhaust Signature Suppressor (GESS) Development for 60KW Diesel Electric Generator" (U). AD C0089816.

2. Final Report, Contract DAAK02-72-C-0286, "Infrared Camouflage of the AN/TPQ-37, MALOR Radar System," Feb. 1976.

3. Final Report, Contract DAAK02-72-C-0286, "Multispectral Camouflage of Four Army Vehicles and Two Generators." AD C004133L.

4. Final Report, Contract DAAK02-72-C-0286, "Multispectral Camouflage for Generator." AD C00590L.

TITLE	DATA SHEET 1208
CAMOUFLAGE USING LOCAL MATERIALS	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

Local materials can be utilized to blend an item with its natural surroundings.

POTENTIAL APPLICATION:

Many items of military equipment can be camouflaged with natural materials, either as the sole camouflage technique or to supplement built-in, add-on, or field applied synthetic camouflage.

DESCRIPTION:

Many items of military equipment have no built-in camouflage or, in some cases, only forest green coloration (See Data Sheet 3008). Natural vegetation, dirt, sand, or rocks can be placed on or around these items for camouflage. Pattern painted equipment can also benefit from this additional camouflage, because pattern painting does not break up regular geometric outlines or characteristic signatures (gun barrels, antennas, windows, etc.); correct placement of local materials can blend these cues into the natural surrounding.

Even equipment that is camouflaged with the lightweight screening system(LSS) (see Data Sheet 2000) or synthetic disrupters can sometimes benefit from selective placement of local materials. Large objects which require two or more LSS modules are especially vulnerable to detection because of their size.

Listed below are some additional factors that should be considered when using local, naturally-occurring materials for camouflage:

Cut vegetation will wilt and lose its natural shape and color in a matter of a few hours to a few days; it therefore needs to be periodically replaced in order to maintain effectiveness.

Soil will also wash off walls and surfaces when it rains and it also needs to be periodically replenished.

Foliage brackets (see Data Sheet 2002) need to be designed into equipment, or provisions made for adding to existing equipment, to facilitate the attachment of natural vegetation.

TITLE	DATA SHEET 1208
CAMOUFLAGE USING LOCAL MATERIALS	PAGE 2 OF 2

Good concealment is possible if the equipment can be located within existing foliage, i.e. eliminating the need to use cut vegetation. Planting natural vegetation around a permanent structure also provides good camouflage.

EXPERIENCE:

Using cut vegetation for blending purposes is one of the oldest forms of camouflage.

More recently, special clips have been designed for holding natural materials on 120mm, 90mm, and 76mm gun barrels of armored vehicles (see Data Sheet 2002).

OTHER CONSIDERATIONS:

Shiny objects on equipment, such as windows and lenses, are not easily hidden by local materials. An opaque material, such as sheets of unincised camouflage cloth (see Data Sheet 3011), should be placed over these cues.

SEE DATA SHEETS: 2001, 3011

REFERENCES:

1. TM 5-200, Camouflage Materials, Department of the Army.

2. FM 5-20, Camouflage, Department of the Army.

TITLE CAMOUFLAGE PATTERN PAINTING	DATA SHEET 1209 PAGE 1 OF 4

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

Pattern painting, when properly employed, reduces the threshold of visibility of the weapon or equipment item. Pattern painting also can be the first step in a more complete camouflage system that includes other techniques.

POTENTIAL APPLICATION:

All major items of TOE tactical equipment are pattern painted at unit level.

DESCRIPTION:

All military vehicles and equipment have characteristic shapes and interior shadows. These signatures contrast with natural surroundings and make the object conspicuous. Pattern painting does much to break up these signature characteristics by using lusterless paint to reduce the glare of highlights, color to reduce contrast with the soil and vegetation, and pattern size, shape, and placement to distort the vehicle's form. The patterns, designed for each type of vehicle, have color areas that cut off corners, avoid straight vertical and horizontal lines, and extend internal shadows in shapes similar to natural features and vegetation. (Reference 1)

The pattern painting designs provide a system that can be adapted to various geographical and seasonal changes by the changing of one or, at most, two colors. The designs also lend themselves to touchup painting with better results than that obtainable with one-color OD vehicles. Slight mismatches in color will not be as noticeable as they are on a solid-colored vehicle.

For any geographic or climatic condition, only four colors of paint are used (see Figures 1 and 2 of Data Sheet 3006). The only exception is winter arctic, which is solid white. When changing from one geographic or climatic condition to another, the shape of the pattern itself does not change; only one or two of the colors that make up the pattern change.

New items of TOE tactical equipment will be painted lusterless forest green at the factory. Since forest green is usually one of the large 45% color areas (Figure 2, Data Sheet 3006), troops will have to pattern paint only three colors.

TITLE	DATA SHEET 1209
CAMOUFLAGE PATTERN PAINTING	PAGE 2 OF 4

The color patterns were designed for world-wide application, and cover a wide range of terrain conditions. It is possible that any given color combination may not be an exact match for some specific local condition. In such a case, the twelve colors available in camouflage paints give the local commander wide latitude to modify the color combination and develop one that more closely matches the local terrain and operating conditions.

Pattern designs are available for most items of Army Tactical Equipment. Further information may be obtained by calling Camouflage Action Line AV354-2654. Figure 1 is a color photograph of a pattern painted armored personnel carrier.

EXPERIENCE:

The pattern painting system for TOE tactical equipment has been in use since 1974. An investigation (Reference 2) was conducted during 1972 and 1973, by a MERADCOM Camouflage Team in conjunction with MASSTER, at Fort Hood, Texas, and involved pattern painting both by troops and professionals, in motor pools and maintenance shops. Among the topics investigated were pattern theory and application, paints and painting, cost, and results for both ground vehicles and helicopters.

OTHER CONSIDERATIONS:

Paints currently available for pattern painting use are described in Data Sheet 3006. A special, removable, arctic camouflage paint is described in Data Sheet 3007. Original forest green paint is described in Data Sheet 3008. Data Sheet 3009 describes an external surface paint that is solar and heat reflecting. A special, low reflective paint, developed to counter the threat of the Russian STRELLA missile, is described by Data Sheet 3010.

SEE DATA SHEETS: 3006, 3007, 3008, 3009, 3010

REFERENCES:

1. TC5-200, Camouflage Pattern Painting

TITLE CAMOUFLAGE PATTERN PAINTING	DATA SHEET 1209
	PAGE 3 OF 4

REFERENCES (Continued):

2. Report number 2090, Camouflage Pattern Painting Report of USAMERDC's Camouflage Support Team to MASSTER, February 1974, Ft. Belvoir, Virginia.

3. TB43-0147, Color, Marking, and Camouflage Patterns Used on Military Equipment Managed by USATROSCOM, December 1975.

4. TB746-95-1, Color, Marking and Camouflage Pattern Painting for Armament Command Equipment, May 1976.

5. TB43-0118, Field Instructions for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelters, 19 December 1975.

6. Report number 2177, Spectral Reflectance Evaluation of Camouflage Detection Photography, USAMERADCOM, May 1976, Ft. Belvoir, Virginia.

7. Military Specification, MIL-E-52798 (ME), 21 May 1976, Enamel, Alkyd, Camouflage.

8. Military Specification, MIL-P-13340C, Paint, Water and Gasoline Thinnable, Camouflage.

9. Military Specification, MIL-C-46168A, Coating, Aliphatic Polyurethane, Low Reflective, Chemical Agent Resistant, Camouflage.

10. AR 750-58, Painting, Camouflage Painting and Marking of Army Materiel.

11. TM 43-0139, Painting Instructions for Field Use.

TITLE	DATA SHEET 1209
CAMOUFLAGE PATTERN PAINTING	PAGE 4 OF 4

Figure 1 Pattern Painted APC

TITLE	DATA SHEET 1210
SHAPE DISRUPTERS for CAMOUFLAGE	PAGE 1 OF 3

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To permit quick reaction camouflage of equipment and sites under more circumstances than are possible or practical with screens or other existing means; especially in a fire fight requiring frequent movement.

POTENTIAL APPLICATION:

SHAPE disrupters can be used with most items of TOE tactical equipment, especially armor and air defense units.

DESCRIPTION:

Disrupters are typically expandable and retractable devices capable of attachment to select locations on military equipment or are capable of free-standing use. One common type of disrupter consists of a center support pole and radial ribs which support the garnishing material (Sheet 2000).

Disrupters are deployed on, and serve to conceal, equipment corners and other characteristic geometrical contours, e.g., dish antennas, wheels, wheel wells, gun barrels, and spotlight lenses. More than one disrupter is generally required to achieve the desired camouflage effect. Since complete hiding or blending of the equipment is not usually practical with disrupters, planning must go into their location, shape, size, and orientation. This planning must include considerations for the probable nature of the threat (unfriendly observation), e.g., low-level or high-level aerial observation or ground observation.

EXPERIENCE:

Significant effort has gone into the development of disrupters for the HAWK missile system. The use of SHAPE disrupters with the HAWK system is shown in figure 1.

TITLE	DATA SHEET 1210
SHAPE DISRUPTERS for CAMOUFLAGE	PAGE 2 OF 3

OTHER CONSIDERATIONS:

Disrupter design should include provisions for:

1. Folding into small packages which have protective covers and which will permit negotiation of terrain in a manner comparable to the item without disrupters.

2. Several sizes and configurations to meet the needs of geometrics of various equipment.

3. Simple replacement, in the field, of the garnish by the equipment operator; this allows replacement of worn or damaged material and also permits changes dictated by geographical or climatic conditions.

SEE DATA SHEET:

REFERENCES:

1. "Test Report for Disruptor Type Comparison," NERA, Inc., Report No. 331-1, N. Stone, May 1974, prepared for USAMERADCOM, Contract No. DAAK02-73-C-0322.

2. "Helicopter Disrupter Set," Memorandum and Photos, 6 October 1972, Thompson. MERADCOM CS&T Reference Center File C-1489.

3. "Hawk Disrupter Design," Final Report, NERA, Inc. Report No. 174-10, December 1973. MERADCOM CS&T Reference Center File C-1785.

4. "The Development, Fabrication, and Demonstration of Full-Scale Models of Disruptor-Type Camouflage Equipment," R. Vergara, T. Hill, G. Riley, 30 April 1974, MERADCOM CS&T Reference Center File C-2102.

TITLE	DATA SHEET 1210
SHAPE DISRUPTERS for CAMOUFLAGE	PAGE 5 OF 5

Figure 1 Use of Bold Shape Disrupters

TITLE	DATA SHEET 1211
CAMOUFLAGE HYDROPLANTING	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To provide natural revegetation of spoiled surfaces to reduce their visibility from the air and to provide stabilization from wind and water erosion.

POTENTIAL APPLICATION:

To establish a rapid, camouflaging cover for use on missile sites, bunkers, base camp perimeters, or other military installations where there are extensive areas of bare soil.

DESCRIPTION:

The recent development of hydroplanting and hydrograssing equipment for use on highway embankments and rights-of-way has provided a technique which is adaptable for military camouflage use. These techniques provide a capability for the establishment of grasses and other types of vegetation by application of a slurry containing water, seed or other plant propagules, fertilizers, and a mulch. Mechanized equipment for hydroplanting is currently available on the civilian market.

Important considerations in hydroplanting for camouflage include: (1) selecting plant species of rapid growth habit which are adaptable to the hydroplanting technique; (2) the availability of appropriate growth-promoting media or substrates and the incorporation of locally available materials; (3) an assessment of the useful life of the proposed vegetation cover and its supporting media; and (4) an assessment of the camouflage properties of the proposed vegetation and its response to infrared or camouflage detection photography, or other surveillance techniques.

EXPERIENCE:

A three-phase program was conducted by the Vegetation Control Division at Fort Detrick, Frederick, Maryland; Phase I established the feasibility of the concept; Phase II was concerned with selection of plant species, species mixtures, and the development of some techniques; Phase III conducted further research on techniques, materials, and equipment, and presented detailed recommendations for the use of hydroplanting to establish camouflage of denuded soil areas.

TITLE	DATA SHEET 1211
CAMOUFLAGE HYDROPLANTING	PAGE 2 OF 2

REFERENCES:

1. Technical Report No. LWL-TR-31B73, "Feasibility of Establishment of Vegetation for Camouflage through Hydroplanting Techniques," J. Frank and W. LeCroy, January 1974.

2. "Establishment of Vegetation for Camouflage through Hydroplanting Techniques," J. Frank, W. LeCroy, K. DeMaree, D. Katchur, and W. Tozer, October 1974.

3. "Establishment of Vegetation for Camouflage through Hydroplanting Techniques," Final Report, F. Smith, L. Boyer, D. Katchur, W. LeCroy, and K. Demaree, July 1975.

TITLE DECOYS	DATA SHEET 1402 PAGE 1 OF 4

CAMOUFLAGE TECHNIQUE ☒ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☐

PURPOSE:

Decoys deceive enemy observers by creating emissions, cues, and signals, which simulate vehicles, tanks, guns, or other standard items of equipment.

POTENTIAL APPLICATION:

Many items of military equipment are candidates for simulation, using decoys, where the level of concealment necessary for survivability cannot be assured. Particular applications will usually involve use of decoys to draw attention or enemy fire away from nearby "real" targets and cause the enemy to waste firepower. Equipment decoys used in the future will normally require a full scale of simulation including electronic, IR, Radar, etc.

DESCRIPTION:

One way of describing decoys is by their fidelity, the degree of detail to which the real item and its properties are copied. The fidelity required must be defined early in the design and development. This definition will come from assessing the sensor threats and the ranges at which those sensor threats must be deceived.

Shape and visual appearance are among the first items considered in the design of a decoy. The overall geometrical form can easily be copied to a high degree of fidelity; large signature cues, e.g., gun barrels or radar transmitter/receiver dishes are considered part of this intrinsic form. Lenses, small antennas, hubcaps, gun sights, and other small cues may be omitted if the fidelity requirements are not great. Standard coloration of the archetype, like original paint, is usually readily available and nearly always should be used with the decoy.

When the deception of sensor threats other than visual observation is also part of the fidelity requirements, then equal design care should be given to deceive threats operating on these principles (See Section 3):

- Photography (including color infrared)
- Infrared energy (thermal, night vision devices, etc.)

- Millimeter-Wave
- Microwaves
- Acoustic, Seismic, Magnetic
- Chemical

Physical (three-dimensional) decoys have been of either rigid or inflatable construction. Rigid decoys offer more permanence of form, intrinsically less maintenance, and less dependence on subsystems (such as an air supply). Handling, packaging, storage, and shipping disadvantages occur with rigid decoys more so than inflatable decoys. Inflatable decoys require an air supply and pressure regulation system, which in turn requires a power supply. Inflatable decoys are lower weight and occupy less packaged volume than the rigid type.

EXPERIENCE:

Most decoy effort in and since WWII was concerned with providing a tactical cover and deception capability. One specific decoy not now in use was the development and fielding of a decoy of high fidelity in the visual and radar regions. It was used by the artillery units employing the archetype and served to protect the real weapon.

Recent decoy development efforts are illustrated in Figures 1 and 2. Figure 1 shows a high fidelity decoy of the M-113 armored personnel carrier. The high fidelity description in this case actually applies only to the static visual appearance, since the decoy is not maneuverable and does not possess a radar cross section or sonic signature similar to the archetype. This decoy is constructed of painted foam bonded to sheets of corrugated aluminum; the folded volume, for packaging and transporting, is 15% of the deployed volume.

Figure 2 is a low fidelity HAWK missile launcher decoy. The decoy missiles are inflatable.

TITLE	DATA SHEET 110[illegible]
DECOYS	PAGE 2 OF 4

REFERENCES:

1. "Complementary Flagging/Disguise/Decoy System for the [illegible] ([illegible]) Helicopter (Phase I)" [illegible], Loerschuk, 15 October 1975.

2. FM 5-90.

Figure 1 M-113 Decoy

TITLE	DATA SHEET 1402
DECOYS	PAGE 4 OF 4

Figure 2 HAWK Missile Decoy (Inflatable Type

TITLE CAMOUFLAGE SCREENS (NETS)	DATA SHEET 2000
	PAGE 1 OF 9

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☒ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To conceal military equipment, installations, and activities from observation by sensor systems utilizing reflected EM energy from the target.

POTENTIAL APPLICATION:

To most combat equipment, installations, and small local activities which are to remain in a static position for relatively short times and for more permanent installations over a longer time where the objective is primarily to defeat effective identification of the target and/or reduce the effectiveness of attack.

DESCRIPTION:

Camouflage screens (nets) are the principle field means employed by most armies to conceal combat positions and equipment. In their modern form, they date from WWI where a countermeasure was needed to defeat the aerial camera. They are also almost universally misunderstood and, therefore, improperly used.

In order to obtain the surface texture scattering of incident illumination and permit as much free air and water vapor passage with as little bulk and weight as possible, screens made for employment in foliated terrains have significant openness in their garnishing. (Garnish is a term used to describe a colored and textured material applied to a net support of cord or wire.) Viewing such a screen against a lighted background (sky) will demonstrate that there is see-through (except at radar frequencies when the screen has been provided with anti-radar capability). Camouflage screens conceal not so much by hiding the target as by casting a shadow within which the target is not discernable, i.e., below the contrast threshhold of the sensor.

Since the target would be perceptible without the screens because of the target's characteristic shadow and reflectance tones, the screen must overcome these if the target is to be concealed; otherwise, the outline or form of the target would be recognizable. It is, therefore, essential that the background and the target under the screen be matched as nearly alike in reflectance as possible or the form will still be perceptible through the screen.

An illustration of this principle familiar to nearly everyone is a thin window curtain (not a drape). On the inside during the day, objects outside can be viewed fairly easily through the curtains; conversely, from the outside, the curtain is a white sheet and the interior of the room is not perceptible. A light object (dish) held near the window on the inside, however, is readily seen from the outside.

A second and related characteristic is that, in order for the screen to function properly some distance between the target and screen is essential. Even properly toned items, to remain concealed, must have both high reflectance surfaces, e.g., windshields, headlights, etc., and deep shadow areas covered to minimize form-revealing contrasts and attention-drawing specular reflectances.

Screens are designed to permit the total installation to be blended into its background. The screens are colored, textured, and patterned to assist in disguising their plan or form and to present a natural appearance. In effect, one is trying to bring the ground up over the target. Screens of any appreciable size, therefore, require an additional application of foliage or other local material to further break up the planar surface by casting shadows on it and to diminish edging effects where the screen meets the ground.

The center 1/3 of flat top screens contained dense garnish. The outer 2/3 contained garnish progressively thinned out until there was no garnish at the edge. Earlier drape nets were also thinned out at the edge but to a lesser degree, which often produced a detectable line when observed from the air. The current modular, lightweight screening system is garnished solid to the edge and requires the user to thin out or blend as is needed but only for one time use or for repeated application to the same item.
Screens for use in deserts and snow do not require the texture and scattering characteristics needed for foliated terrains. The use of closer weave or knotted materials, such as shrimp netting, are acceptable for desert or snow camouflage applications. They must still not have a smooth surface, or shine will result, but the texture can approach that of sand. In current practice, the desert and snow screens utilize small incising (See Figure 5 of Data Sheet 3011) for all the garnish patterns. The Woodland screens employ a mix of small and large incising (See Figure 6 of Data Sheet 3011) to simulate blade-like and leaf-like geometries occurring in nature. The snow screen incorporates a special white garnishing which simulates the reflectance (See Figure 11 of Data Sheet 3011) of snow in the

near ultraviolet as well as the visible regions of the electromagnetic spectrum. One side of the snow screens has all-white garnishing, while the other side (mixed color side) contains some forest green and Woodland tan patterns on a predominantly white background; this side is used to simulate partial snow cover. The snow screens also employ specially designed components for easier use in extremely cold environments. The color specifications for desert screen color patterns are the result of studies of U. S. and Middle Eastern desert terrain colors.

Each lightweight screening system includes a support system for elevating the screen above the equipment that is being camouflaged and for fixing the edges to the ground or to adjoining screens (see Figure 3). The support poles are sectional and from one to three pole sections are typically used, with a three-armed batten spreader assembly, to support camouflage screens. The edge joining of two screens is accomplished using the quick-connect-disconnect (QCD) device; the QCD consists of brackets permanently attached to the net edges, and pins attached to separate lanyard cords. When the QCD's are assembled, with all the pins oriented in the same directions, disassembly is quickly accomplished by pulling on the appropriate end of the lanyard cord.

Selecting screen size for application to equipment is usually underestimated. (See Figures 1 and 2 for physical data on camouflage screens.) The installed screen, in most instances, to achieve a concealed target and blended installation, must be tied into existing terrain features at an angle to the ground of less than 60° and preferably closer to 30°. The height versus the area of an installation is important. Where choice of position permits, natural defilade should be sought. In open terrain there is no solution to this problem.

While screens have been improved in regard to color, texture, weight, bulk, water absorption, durability, reliability, and spectrozonal response, the world is a big place and it is logistically possible to supply only a limited variety of such material. Localization is necessary, therefore, to achieve good context with background. Finally, the installation and removal of screens require work and time. If the installation is to remain effective, it must be constantly repaired and maintained.

Camouflage screens are a valuable, though limited, solution to concealment. They are not effective in controlling heat emissions, sounds, and chemical signatures. They also require the item to remain in a static position, whereas other more dynamic camouflage is required for combat equipment subject to constant movement and engagement with an enemy.

EXPERIENCE:

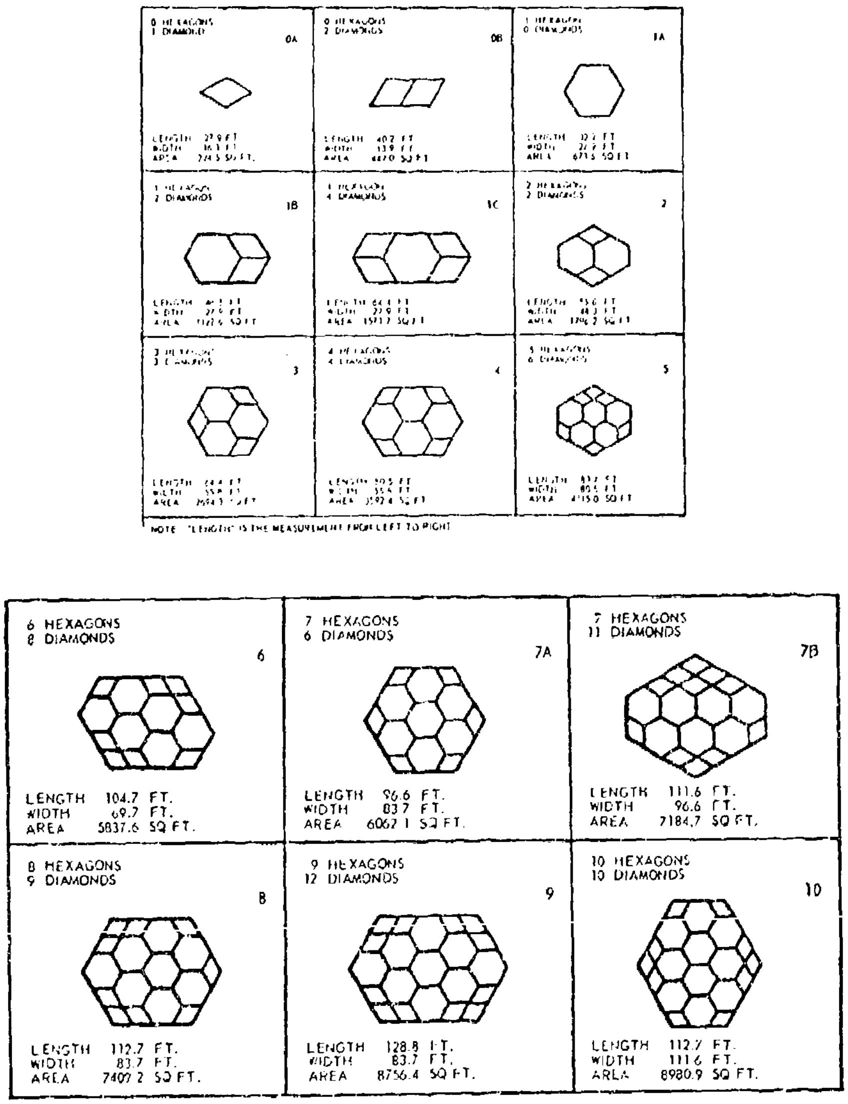
Nearly all armies employ camouflage screens. Some provide materials which troops combine to produce screens; others provide mass produced end products. All have concealment capacity in the visible range, and most have concealment capacity in the near-IR and UV ranges. The new army material has good response in the UV, Visible, NIR, and Radar regions of the spectrum. Figures 4, 5, 6, and 7 show, respectively:

1. A color infrared (CD) photograph of Woodland (Summer side) screens concealing items of military equipment,

2. A standard color photograph showing an erected Desert screen with the tan side up,

3. A standard color photograph of a deployed Arctic screen with the mixed color side up, and

4. A standard color photograph showing a Woodland screen deployed with the Winter side up.



NOTE: "LENGTH" IS THE MEASUREMENT FROM LEFT TO RIGHT.

Figure 1 CONFIGURATION DATA

WEIGHT AND VOLUME

Weight and volume of one packaged camouflage screen system is:
65 lb.; 7.1 cu ft.

Weight and volume of one packaged camouflage support system is:
68 lb.; 3.3 cu ft.

General formula for calculating the modular dimensions necessary for camouflaging an item of equipment.

Module(s) Length = 4H + L

Module(s) Width = 4H + W

H = Height of the equipment item

L = Length of the equipment item

W = Width of the equipment item

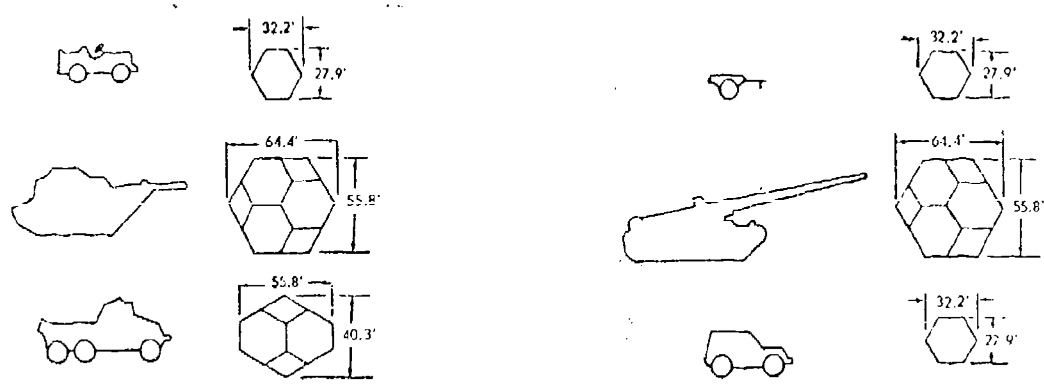


Figure 2 TYPICAL APPLICATIONS

TITLE	DATA SHEET 2000
CAMOUFLAGE SCREENS (NETS)	PAGE 7 OF 9

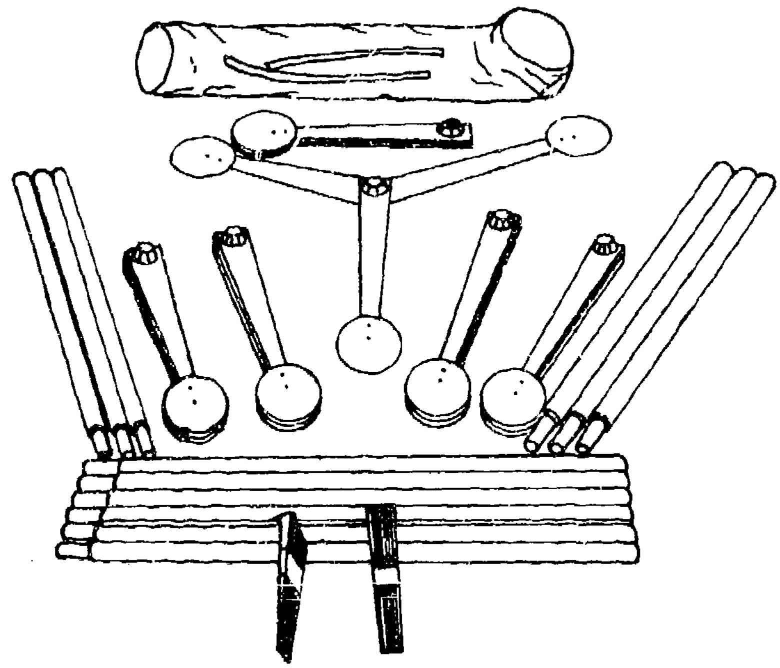


Figure 3a Support System Components: Carrying Case, Batten Spreaders, Poles, and Stakes

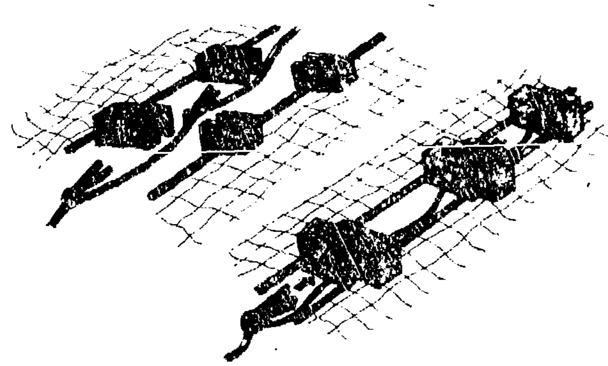


Figure 3b Quick Connect-Disconnect System: Brackets Attached to Edge of Net and Pins Attached to Lanyard Cord

Figure 4 Woodland Screen, Summer Side (Color IR Film)

Figure 5 Desert Screen, Tan Side

Figure 6 Arctic Screen, Partial Snow Side

Figure 7 Woodland Screen, Winter Side

TITLE	DATA SHEET 2001
SMOKE SCREENS	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☒ CAMOUFLAGE MATERIAL ☐

PURPOSE:

This materiel is used for screening targets from the enemy, primarily during attack conditions.

POTENTIAL APPLICATION:

This materiel can be used to temporarily hide combat equipment, to confuse the enemy as to target location, and to reduce the effectiveness of attack (hitability).

DESCRIPTION:

The following materiel is stocked within the Army and can be used for smoke generation:

Smoke Pot, Floating, SGF2, AN-M7A1, MIL-S-51235B. This smoke pot can be fired remotely by electronic control or manually. It emits a dense cloud of smoke for up to 15 minutes and can be used on land or in water.

Smoke Pot, Oil, SGF2, M6, MIL-S-11141F. This smoke pot is manually fired and has been used mainly in training exercises. It emits a continuous, small cloud of smoke for a specific time interval.

Smoke Bomb, MIL-B-60304(1), MIL-B-10746D. This bomb is effective for concealing installations for a short period of time.

Dyes for colored Smoke Mixtures, MIL-D-3613(1), MIL-D-48178, MIL-D-3709, MIL-D-3668B, MIL-D-21354. These dyes for coloring smoke have been used for signalling purposes only thus far. The addition of different colors to smoke could add to enemy confusion or distraction.

Smoke Generator, Mechanical, Pulse Jet, ABC-M3A3, MIL-G-51066C. This generator is used for producing smoke screens of longer duration.

Grenade, Hand, Smoke, MIL-C-12327E, MIL-G-12326H, MIL-G-12237B. These grenades are used for localizing small smoke screens. Multiple utilizations can create decoys as well as hide equipment.

TITLE SMOKE SCREENS	DATA SHEET 2001 PAGE 2 OF 2

Smoke Pot, 30 pound, MIL-S-13183B. This smoke pot produces a white smoke screen. It is mechanically or electrically ignited.

Smoke Tank, Airplane, M10, MIL-S-13610B. This tank has been specifically designed for releasing smoke from aircraft.

EXPERIENCE:

Smoke blankets have been used over friendly areas to hinder aerial observation and precision bombing. Smoke blankets are formed by smoke generators, which are mechanical generators used to volatilize oil, and by smoke pots, that produce smoke by the combustion of a pyrotechnic composition.

Smoke haze is used mainly to conceal activities from observation and ground fire. Although formed in a manner similar to smoke blankets, smoke haze is usually less dense.

A smoke curtain is a dense vertical formation used to restrict ground observation. Smoke curtains are sometimes by-products of artillery weapons.

OTHER CONSIDERATIONS:

Although smoke is generally described as a materiel for hiding military equipment, smoke is also effective as a decoy.

REFERENCES:

1. AMC Pamphlet. "Research and Development of Materiel, Engineering Design Handbook, Military Pyrotechnics Series Part Three - Properties of Materials Used in Pyrotechnic Compositions," AMCP 706-187, October 1963.

2. AMC Pamphlet,"Research and Development of Materiel, Engineering Design Handbook, Military Pyrotechnics Series Part Two - Safety, Procedures and Glossary," AMCP 706-186, October 1963.

3. Miscellaneous Paper M-76-21,"Camouflage Materials for Fixed - Installation Concealment," Mobility and Environmental System Laboratory, December 1976. AD A033933.

TITLE	DATA SHEET 2002
CAMOUFLAGE FOLIAGE BRACKETS AND SPRING CLIPS	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☒ CAMOUFLAGE MATERIAL ☐

PURPOSE:

The brackets are used for attaching natural or synthetic camouflage materials to items of military equipment. Spring clips are used for the same purpose on gun tubes.

POTENTIAL APPLICATION:

To all items of military equipment.

DESCRIPTION:

This materiel is useful for attaching foliated twigs and branches to equipment, or for securing pieces of netting and other synthetic garnishments.

The camouflage bracket assembly described by MS-39322 is a general purpose materiel for all items of equipment.

The spring clip defined by MIL-C-12073C was designed for use when camouflaging armored vehicle gun barrels, e.g., 120mm, 90mm, and can be used on other structures as well.

EXPERIENCE:

This materiel concept evolved from the practice of attaching local foliage to armor during WWII. The U.S. Army in Europe welded Landing Mat to the sides and turrets of tanks to make this practice more convenient. Shortly after the war ended, experimentation by the Engineer Research and Development Laboratories evolved the simpler bracket and spring clips system. Foreign countries adopted and used the system (and still do) and acceptance by the U.S. Armored Forces is beginning. Properly applied and used in terrains where pine and other evergreen foliage is available it is a good solution for mobile equipment during actual engagements.

OTHER CONSIDERATIONS:

There is the requirement for proper installation of the foliage and there will be some interference with clear fields of vision. It is an inexpensive materiel approach, but does shift the burden of proper employment and work onto the field troops. New developmental work has been conducted to update foliage brackets.

TITLE	DATA SHEET 2002
CAMOUFLAGE FOLIAGE BRACKETS AND SPRING CLIPS	PAGE 2 OF 2

SEE DATA SHEETS: 1208

REFERENCES:

1. MS 39332 - Bracket Assembly, Camouflage
2. MIL-C-12093C - Clip, Spring, Camouflage, Armored Vehicle, For 120mm and 90mm Gun Barrels.
3. Emerson, W. and Zaremba, W., <u>Final Report Joint DARCOM - TRADOC Pilot Program to Camouflage the M60A1 Tank</u>, July 1977.

M60A1 Tank with Foliage Brackets.

TITLE	DATA SHEET 2003
CAMOUFLAGE HELICOPTER CANOPY GLARE COVERS	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☒ CAMOUFLAGE MATERIAL ☐

PURPOSE:

To minimize the probability of detection, by reducing the glare (shine) of a helicopter canopy.

POTENTIAL APPLICATION:

This materiel is designed for use with parked helicopters.

DESCRIPTION:

The canopy glare covers consist of a rip stop nylon material that is cut to the same dimensions as the canopies of the helicopters. The cover fits over the nose of the aircraft and extends toward the rear of the aircraft to cover all canopy sections. The cover is secured to hard points on the aircraft fuselage. Color patterns may be applied to the cover to correspond with the color of the fuselage. The material also provides a textured surface and weighs generally less than four pounds and folded covers occupy approximately one cubic foot when packed for storage or transportation. The covers were designed to be quickly and easily attached and detached. Because of their low weight and bulk, they can be carried on board the helicopter

When in position, the cover is rated as very effective in reducing the glare and shine of the helicopter canopy. The rip stop nylon covers tend to create their own limited shine, but this is considered minimal when compared to the shine from a canopy without a cover.

EXPERIENCE:

Early prototypes of the canopy glare cover were demonstrated during the MASSTER Attack Helicopter Squadron Test, February 1973. Covers for the AH-1G, OH-58, and UH-1 helicopters have been evaluated. Subsequent evaluations have been conducted at Ft. Bragg in 1977, with excellent results.

TITLE	DATA SHEET 2003
CAMOUFLAGE HELICOPTER CANOPY GLARE COVERS	PAGE 2 OF 2

OTHER CONSIDERATIONS:

Users indicate the glare cover is simple and quick to employ (2 to 5 minutes) and easy to store on board any helicopter.

The material is only partially impervious to light and, when light enters the canopy, it is reflected back toward the cover. This makes the cover appear slightly lighter than the fuselage.

Because of the thin construction material the cover tends to flutter. This has not proven to be a serious source of visual detection, but it has caused other minor problems. First, because the surface of the cover does not continuously maintain contact with the canopy, dust particles were able to reach the canopy surface. The movement of the cover by the wind resulted in minor scratches to the canopy surface.

SEE DATA SHEETS: 1204, 3006

REFERENCES:

1. Camouflage Evaluation Report (Phase 1), MASSTER Test Report No. FM 153, 21 January 1974.

TITLE	DATA SHEET 3000
RADAR ABSORBING MATERIAL-FLAT PLATE, RESONANT	PAGE 1 OF 3

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

To reduce radar cross section over a narrow band of frequencies.

POTENTIAL APPLICATION:

For use in reduction of radar signature against a given threat frequency.

DESCRIPTION:

Flat resonant radar absorbing material (RAM) is of two constructions. The first is the Salisbury screen which consists of a thin sheet of lossy material spaced one-quarter wavelength from a surface of high conductivity. The thin sheet consists of a mixture of carbon, graphite, or conductive wires having a surface resistance of 377 ohms per square. The highly conductive surface is usually the mounting surface. The second construction, sometimes called a Dallenback layer, is a homogeneous lossy material backed by a metallic surface. The lossy material is usually a carbon foam or silicone rubber mixture.

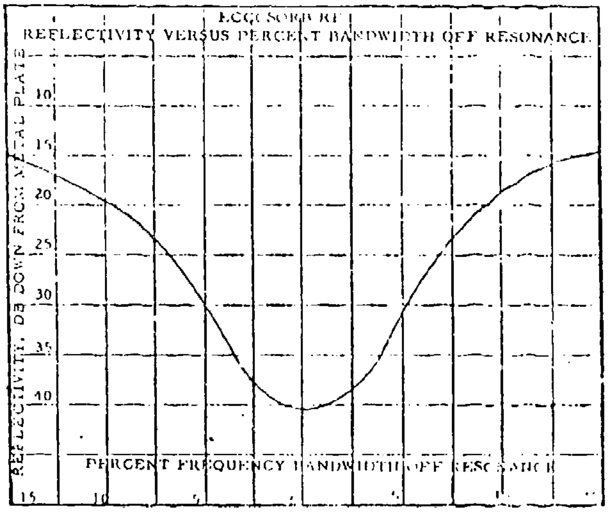
The Salisbury screen is the lightest and most flexible, weighing 0.05 to 0.5 pound per square foot. The solid laminate layer, although much heavier, withstands a more severe environment.

The Dallenback construction tolerates the most extreme environment. The laminate is generally based on a silicone composition which will withstand temperatures of -65° to 325°F. It is not affected by out door exposure and is completely impervious to moisture.

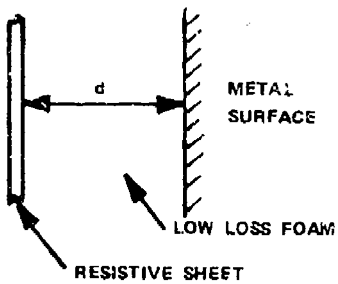
Rugged Salisbury constructions have been fabricated; however, flexibility is sacrificed.

Resonant RAM affords the smallest thickness, 2 to 1/8 inches over a frequency range of 2 to 18 GHz.

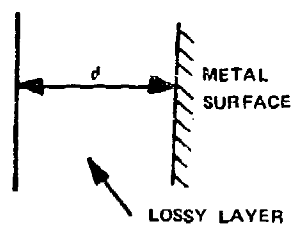
Typical radar response and construction are shown in the following illustrations:



Salisbury Screen



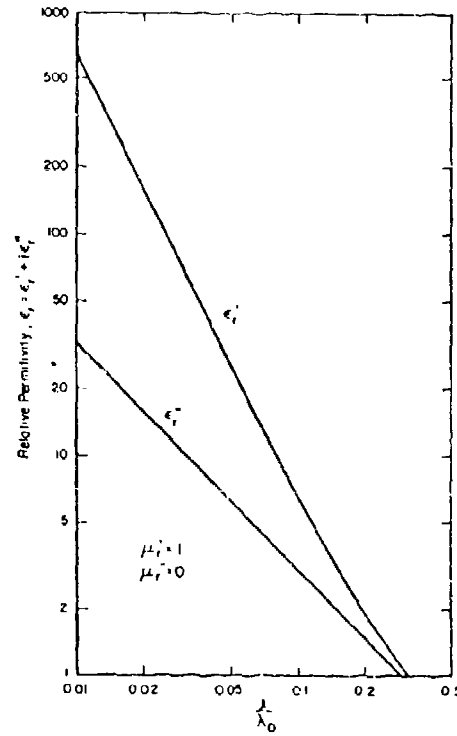
Dallenback Layer



The lossy Salisbury sheet is generally protected by a strong nylon reinforced plastic. The RAM assembly is very flexible thereby facilitating any surface mounting. The standard absorber is designed for best performance at normal incidence. Standard sizes of 24" x 24" are commercially available. Mounting can be easily made with adhesives having high initial tack.

TITLE	DATA SHEET 3000
RADAR ABSORBING MATERIAL-FLAT PLATE, RESONANT	PAGE 3 OF 3

For the Dallenback absorber, the material electrical characteristics are typified by the graph below:



The values of ϵ_r', ϵ_r'' versus the layer thickness giving a zero normal-incidence reflection coefficient for a homogeniaous layer with $\mu r - 1$.

SEE DATA SHEETS: 1203

REFERENCES:

Commercial sources of this material are:

1. Emerson Cumming, Eccosorb RF, SF, MX 410
2. McMillan Radiation Labs, Type T
3. Plessy Incorporated, Type WM
4. Advanced Absorber Products

TITLE RADAR ABSORBING MATERIAL - FLAT PLATE, BROADBAND, GRADED	DATA SHEET 3001 PAGE 1 OF 4

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

To reduce target radar cross section over a broad band of radar frequencies.

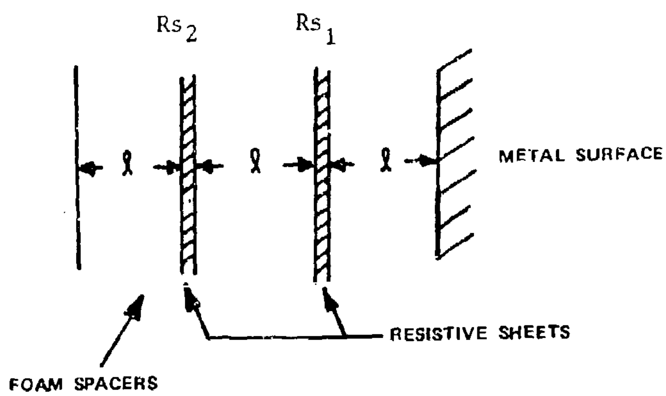
POTENTIAL APPLICATION:

Tanks, shelters, vehicles with large corner geometry.

DESCRIPTION:

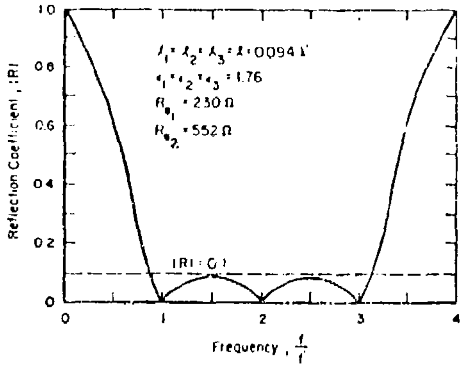
Absorption over a broad frequency band can be obtained by gradually increasing the loss as the incident field propagates into the material. This loss can be either distributed or lumped into discrete layers of thin resistive sheets oriented parallel or perpendicular to the direction of propagation of the incident wave.

One type, the Jaumann design, utilizes thin resistive sheets, analagous to the Salisbury screen. The resistance of the sheets decreases exponentially toward the metallic mounting surface.



TITLE	DATA SHEET 3001
RADAR ABSORBING MATERIAL - FLAT PLATE, BROADBAND, GRADED	PAGE 2 OF 4

The frequency dependence for such an absorber is shown in the following graph. The input impedance of an absorber of this type can be obtained using the theory for arbitrary layered media. The upper frequency limit occurs when the spacer thickness is electrically one-half wavelength. The lower limit occurs when the overall thickness is less than one-half wavelength.



Normal-incidence reflection coefficient of a three-layer Salisbury screen versus frequency.

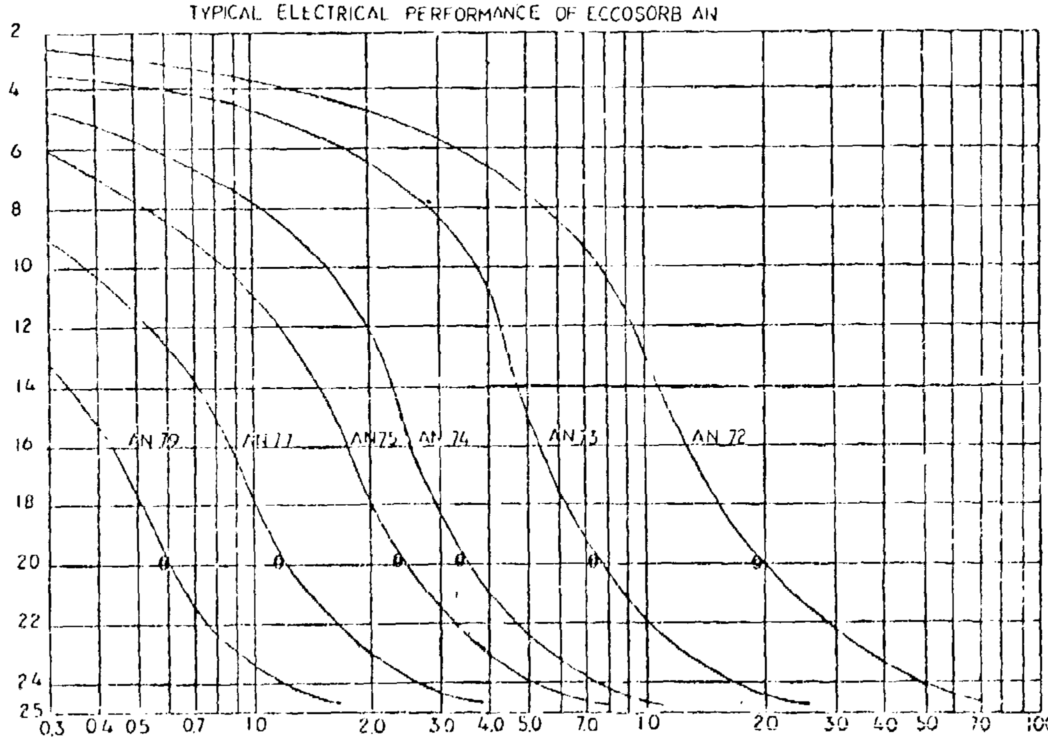
Typical construction utilizes closed cell polyethylene spacers and a film deposition of carbon for the resistive sheets. Sheet sizes are 24" x 24", and for an overall thickness of 1 3/16 inches weighing 0.5 pound per square foot, will provide less than 2% reflectivity from 2.5 to 12GHz. The construction is weatherproof, fuelproof, and flexible.

Numerous solutions for inhomogenous configurations have been investigated and was generally categorized into linear, exponential, quadratic, etc., distributions. However, because of nearly impossible manufacturing techniques, the best approximation is achieved through the fabrication of several discreet layers having electrical properties that approximate the desired mathematical distribution.

TITLE	DATA SHEET 3001
RADAR ABSORBING MATERIAL - FLAT PLATE, BROADBAND, GRADED	PAGE 3 OF 4

The most practical configuration is the dielectric gradient RAM where three or more layers of carbon loaded polyurethane foams are incorporated in a sandwich construction. Typical radar performances of several thicknesses of commercially available absorbers are shown below.

TYPICAL ELECTRICAL PERFORMANCE OF ECCOSORB AN



θ = LOWEST FREQUENCY FOR 1% MAXIMUM REFLECTIVITY

TITLE	DATA SHEET 3001
RADAR ABSORBING MATERIAL - FLAT PLATE, BROADBAND, GRADED	PAGE 4 OF 4

An obvious advantage of the volume lossy design as compared to the Jaumann design is the improvement in performance at higher frequencies.

Although a gradient is implied, it is nearly impossible to match the first outer layer to free space; therefore, the mechanism of continuous absorption is not fully realized. Consequently, the layer dimensions must be selected to provide a vector sum reflection at the initial interface to cancel the original reflected component.

The loaded foam layered construction is available in flexible foam assemblies. The thickness is inversely proportional to frequency; ¼ inch for 20 GHz and above, and 4½ inches for 0.6 GHz and above. Respectively, the weight is 0.1 to 2 pounds per square foot.

Use of honeycomb spacers can provide graded or Jaumann absorbers with high structural integrity. For the graded, thick single layers of phenolic honeycomb are dipped and successively re-dipped to lesser depths in lossy film forming materials to achieve the desired dielectric gradient. For an overall thickness of 1 inch, weighing 2 pounds per square foot, such a panel exhibits a column compression strength of 3800 pounds per inch.

SEE DATA SHEETS: 1203

REFERENCES:

A commercial source of this type of material is:

Emerson Cumming Type AN, ANW, ANP, RM.

TITLE	DATA SHEET 3002
RADAR ABSORBING MATERIAL - FERRITE	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAG MATERIAL ☒

PURPOSE:

To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATION:

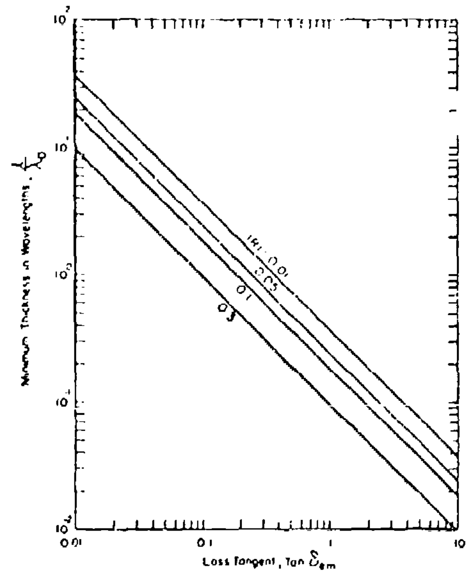
Tanks, shelters, vehicles, with large corner geometry.

DESCRIPTION.

Neglecting any variation of basic electrical properties of a material, permeability (μ) and permittivity (E), the reflection from a material is zero, if μ = E. With sufficient thickness and large enough loss so that the reflection from any metal backing can be neglected, a very thin broadband absorber can be fabricated. In general the only materials capable of such accomplishment are the ferrites. A lossy mixture of a high μ (ferrite) material, and a high E (barium titanate) material can be used effectively for wave absorption if the ratio μ/E is equal to that of free space. The mixtures constitutes a physical discontinuity, but the wave enters it without reflection. The velocity of the wave is reduced and large attenuation can occur in a short distance. The following graph gives curves of minimum electrical thickness versus loss tangent for various desired values of reflection.

A commercially available ferrite absorber has a thickness of 0.04 inch, weight 1.0 pounds per square foot, and averages 10% reflection from 4 to 10 GHz. Although available in thin sheets, tile varieties offer good performance at low frequencies.

TITLE RADAR ABSORBING MATERIAL - FERRITE	DATA SHEET 3002
	PAGE 2 OF 2



Minimum thickness of $\mu = \epsilon$ absorber necessary to give a specific normal incidence reflection coefficient versus the loss tangent of the material.

SEE DATA SHEETS: 1203

REFERENCES:

A Commercial source of this type of material is:

Emerson Cumming Type NZ, FGM, UPF.

TITLE	DATA SHEET 3003
RADAR ABSORBING MATERIAL - LOW DENSITY	PAGE 1 OF 1

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATION:

Tanks, shelters, vehicles, with large corner geometry.

DESCRIPTION:

A good absorber material match to free space can be accomplished by using materials of very low density for which the dielectric constant (E) is very near that of free spaces. Absorption is accomplished by incorporating a small amount of loss and using relatively thick material, electrically.

Typical examples of this material are hair-mat types consisting of a loosely spaced mat of lossy fibres. Low density plastic foams, such as styrofoam having small amounts of carbon particles have been incorporated. This type of absorber is most suitable for laboratory environments and is not a likely candidate for camouflage application.

A 20dB absorber having an 8-inch thickness will function down to 0.5 GHz. These absorbers are usually limited to about 20dB in performance. Density is about 4 oz per square foot for a 2-inch thickness.

SEE DATA SHEETS: 1203

REFERENCES:

A commercial source of this type of material is:

Emerson Cumming Type H

TITLE	DATA SHEET 3004
RADAR ABSORBING MATERIAL-CIRCUIT ANALOG	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATION:

Reduce radar cross section in harsh environments; i.e., engine intakes.

DESCRIPTION:

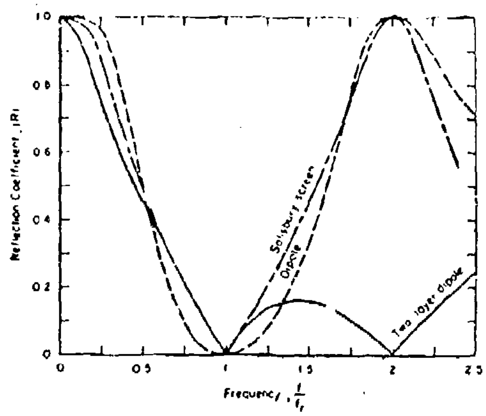
The advantages of CA material in RAM designs are wider bandwidth, smaller thickness, fewer sheets required, better control of absorption values and the ability to design around thicker skins. The use of CA materials will permit the design of high performing systems that can meet the structural requirements of advanced weapon systems.

These absorbers are characterized by thin sheets of material, usually Kapton, having printed geometric arrays resembling printed circuits, but having specific surface impedances separated by lossless dielectric layers. The Salisbury screen is perhaps the simplest example of CA absorber. However, instead of using resistive sheets, a dipole array of known geometry can, with the use of network theory, be designed to provide specific impedance versus frequency characteristics.

Development of CA remains classified and as such, no commercial availability is known.

A comparative response of a CA absorber is shown in the following graph.

TITLE	DATA SHEET 3004
RADAR ABSORBING MATERIAL-CIRCUIT ANALOG	PAGE 2 OF 2



Comparison of the Frequency Response of Single-layer Dipole, and Single-layer Salisbury-screen Absorbers.

SEE DATA SHEETS: 1203

REFERENCES:

A commercial source of this material is:

North American Rockwell, Tulsa, Oklahoma

TITLE	DATA SHEET 3005
RADAR ABSORBING MATERIAL-GEOMETRIC TRANSITION	PAGE 1 OF 1

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

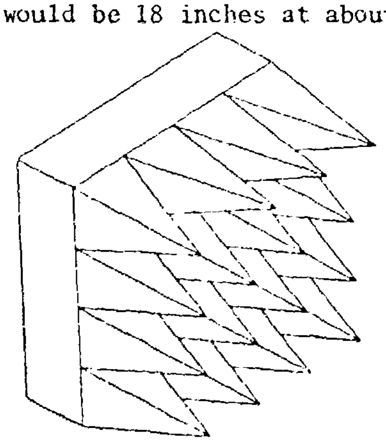
To reduce target radar cross section over a broad band of radar frequencies.

POTENTIAL APPLICATION:

On items/systems where the highest available degree of protection is required and where the absorber's fragility and bulk are not factors.

DESCRIPTION:

In order to achieve lower reflection than is available in most flat plate absorbers (20dB), the subject absorber is characterized by a geometrical transition from free space into a lossy media. This class of absorbers usually takes the form of pyramids or wedges of synthetic sponge rubber or plastic foam which is loaded with an electrically lossy material (carbon). A sketch of a pyramidal absorber is shown below. The geometrical transition may be also combined with an electrical transition by increasing the loss toward the base of the pyramids. Absorbers of this type have reflection losses of 40dB or more for thicknesses of one-quarter free space wavelength. Also better angular performance is available; 40dB up to 50 to 60 degrees. For 1GHz and up, typical thickness would be 18 inches at about 1.2 pounds per square foot.



Geometric Transition Absorber

SEE DATA SHEET: 1203

REFERENCES:

A commercial source of this material is:

Emerson Cumming Type VAP, SPY, WG, HPY, PHD, RMP, FBC

TITLE	DATA SHEET 3006
CAMOUFLAGE PAINT FOR PATTERN PAINTING	PAGE 1 OF 11

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

To minimize detection of objects by visual observation or photographic techniques. Military objects possess characteristic signatures of color, shine, shape and shadow, pattern painting helps to eliminate.

POTENTIAL APPLICATION:

All three paints described in this data sheet have application to field pattern painting all forms of mobility equipment.

MIL-E-52798A is primarily used as a field applied pattern paint, but it can also be used as the Forest Green base coating on new equipment, when the longer drying time of this material is not a factor. It replaces TT-E-527.

MIL-P-13340C is strictly used for pattern painting in the field where only water or gasoline is to be used as the thinner.

MIL-C-46168A is used for pattern painting in the field where chemical, biological and radiological (CBR) resistance is required. The base for this paint is a specially formulated polyurethane designed to resist chemical or biological attack.

DESCRIPTION:

Camouflage pattern painting consists of wavy, irregular patches of color applied to the vehicle or equipment surface. Standard pattern designs have been developed for many items of equipment. Although there are 12 standard camouflage colors, only four of these are used at one time for an item of equipment. Standard designs are shown in the reference cited on the last page of this data sheet. The references also give instructions for surface preparation, priming, and techniques and tips for painting. Attached is a sketch of the pattern painting design for the M113 personnel carrier (Figure 1), and tables showing color abbreviations and distributions for geographic or climatic changes.

The paint colors approximate natural vegetation and terrain colors to a significant degree. The proper selection of colors and pattern shapes maximizes the camouflage effect. The spectrophotometric curves of the individual colors are shown in figures 3 through 9.

The visible color is specified by the CIE (International Commission on Illumination) notation system and NBS (National Bureau of Standards) color difference tolerance limits. The CIE chromaticity coordinates, x and y, are calculated from the spectrophotometric data and are shown in figure 11. The NBS tolerances for each color characteristically take the form of an ellipse. The 2.0 NBS ellipses for the colors are shown in the attached figures. The third visible color variable, CIE "Y" or "apparent reflectance" is also calculated from the spectrophotometric data and the tolerances are shown in figure 10. "Y" is a function of the surface brightness and is independent of the colors' chromaticity.

Also specified for these paints, and shown in the attachments, are special properties for the four green colors (forest green, light green, dark green and olive drab): The visible red reflectance (R), the near-infrared reflectance (NIR), the ratio of NIR to R, and the shape of the spectrophotometric curve through these two regions. Tolerances for these properties are shown in the attached tables and figures. Also specified and controlled are the average NIR reflectances for the other colors, so the proper blending will occur in color infrared photographs.

In the case of the four green colors mentioned in the preceding paragraph, the R and NIR properties are important for simulating the spectrophotometric response of chlorophyll. Live vegetation renders a magenta color in color infrared photograhs, while most synthetic greens render a turquoise color; and explanation of the spectrophotometric requirements of camouflage greens is given in Reference 6.

Another important property of all colors of these camouflage paints is the extremely low specular gloss. Gloss will cause the color to "wash out" of surfaces at certain sun and viewing angles, thus destroying the advantages of camouflage coloration.

EXPERIENCE:

Camouflage pattern painting has been successfully employed for several years on mobility equipment throughout the U.S. Army. Pattern painting has demonstrated its effectiveness as a camouflage technique in reducing the probability of target acquisition, by air or ground observations which utilize visual or near-infrared sensors.

OTHER CONSIDERATIONS:

Of the three types of paint described within this Data Sheet, only MIL-P-13340C is available in the white color. This white will not simulate snow when viewed by sensors utilizing ultraviolet reflection. Whenever a choice is possible, the temporary white paint of MIL-P-52905 should be used when the objective is to achieve snow-like reflection throughout the spectral range of 350 to 900 nanometers wavelength. The MIL-P-13340C white spectral curve exhibits a rapid drop-off in reflection below 420 nanometers. Refer to Data Sheet 3007 for a description of MIL-P-52905.

REFERENCES:

1. TC5-200, Camouflage Pattern Painting

2. Report number 2090, Camouflage Pattern Painting Report of USAMERDC's Camouflage Support Team to MASSTER, February 1974, Ft. Belvoir, Virginia.

3. TB43-0147 Color, Marking and Camouflage Patterns Used on Military Equipment Managed by USATROSCOM, December 1975.

4. TB746-95-1 Color, Marking and Camouflage Pattern Painting for Armament Command Equipment, May 1976.

5. TB43-0118, Field Instructions for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelters, 19 December 1975.

6. Report number 2177, Spectral Reflectance Evaluation of Camouflage Detection Photography, USAMERADCOM, May 1976, Ft. Belvoir, Virginia

REFERENCES (CONTINUED):

7. Military Specification, MIL-E-52798 (ME), 21 May 1976 Enamel Alkyd, Camouflage.

8. Military Specification, MIL-P-13340C Paint, Water and Gasoline Thinnable, Camouflage.

9. Military Specification, MIL-C-46168A Coating, Aliphatic Polyurethane, Low Reflective, Chemical Agent Resistant, Camouflage.

10. AR 750-58, Painting, Camouflage Painting and Marking of Army Materiel.

11. TM 43-0139, Painting Instructions for Field Use.

TITLE	DATA SHEET 3006
CAMOUFLAGE PAINT FOR PATTERN PAINTING	PAGE 5 OF 11

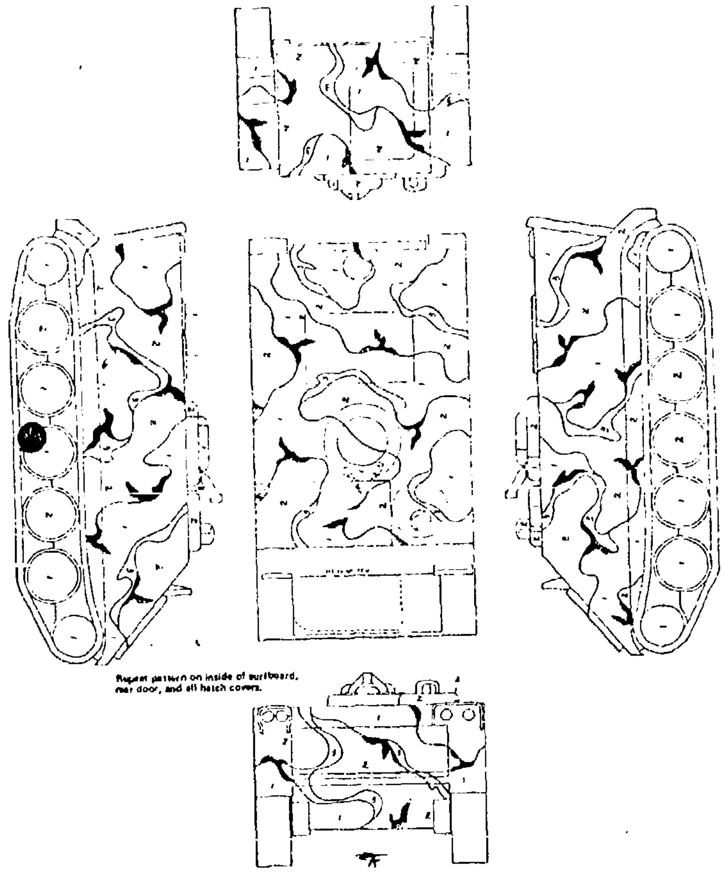


Figure 1 Pattern Painting Design for the M113 Personnel Carrier

TITLE	DATA SHEET 3006
CAMOUFLAGE PAINT FOR PATTERN PAINTING	PAGE 6 OF 11

CONDITION	COLOR DISTRIBUTION 45%	45%	5%	5%
	COLOR NUMBER 1	2	3	
Winter US & Europe - verdant[1]	FG	FD	S^3	BL
Snow - temperate w/trees & shrubs[2]	FG	W	S^3	BL
Snow - temperate w/open terrain[2]	W	FD	S^3	BL
Summer US & Europe - verdant[1]	FG	LG	S^3	BL
Tropics - verdant	FG	DG	LG^3	BL
Gray desert	S	FD	EY^3	BL
Red desert	ER	EY	S^3	BL
Winter Arctic	W	W	W	W

Notes:

[1] *Verdant means generally green—in summer due to trees, shrubs, and grass; in winter due to evergreens.*

[2] *This color combination is for use only in areas that occasionally have snow which does not completely cover the terrain, thus leaving trees or patches of soil bare.*

[3] *This 5% color should be the camouflage color that matches most closely the color of the soil in the local area. A typical color for such use is sand, but earth red, earth yellow, or one of the others may be closer to the predominant soil color and, in that case, should be used.*

NO.	ABBREVIATION	COLOR
1	W	White
2	DS	Desert sand
3	S	Sand
4	EY	Earth yellow
5	ER	Earth red
6	FD	Field drab
7	EB	Earth brown
8	OD	Olive drab
9	LG	Light green
10	DG	Dark green
11	FG	Forest green
12	BL	Black

Figure 2 Camouflage Pattern Painting Color Chart for Geographic and Climatic Changes, and Table of Color Abbreviations

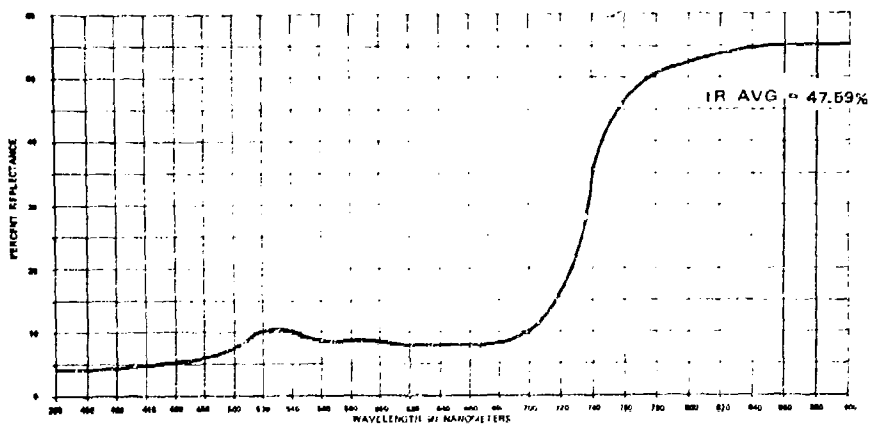


Figure 3 Dark Green Spectral Reflectance

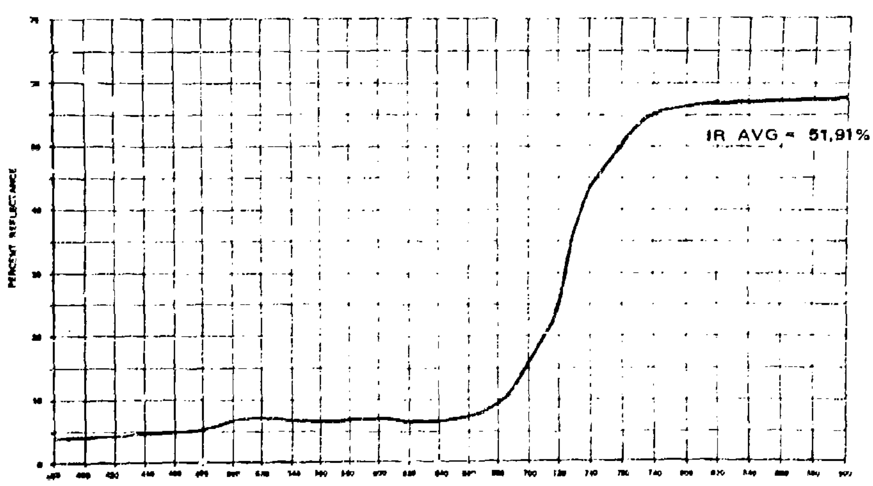


Figure 4 Forest Green Spectral Reflectance

TITLE

CAMOUFLAGE PAINT FOR PATTERN PAINTING

DATA SHEET 3006

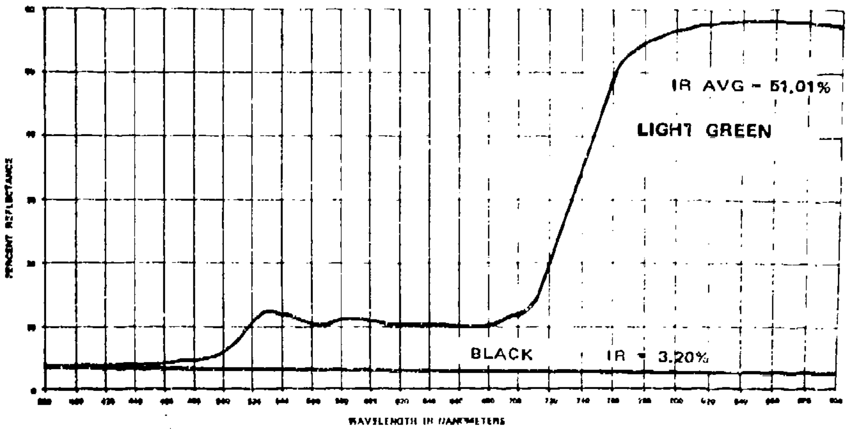


Figure 5 Light Green and Black Spectral Reflectances

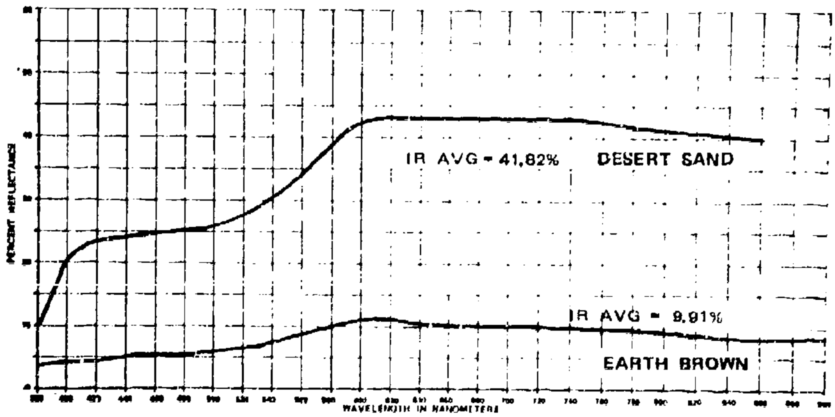


Figure 6 Desert Sand and Earth Brown Spectral Reflectances

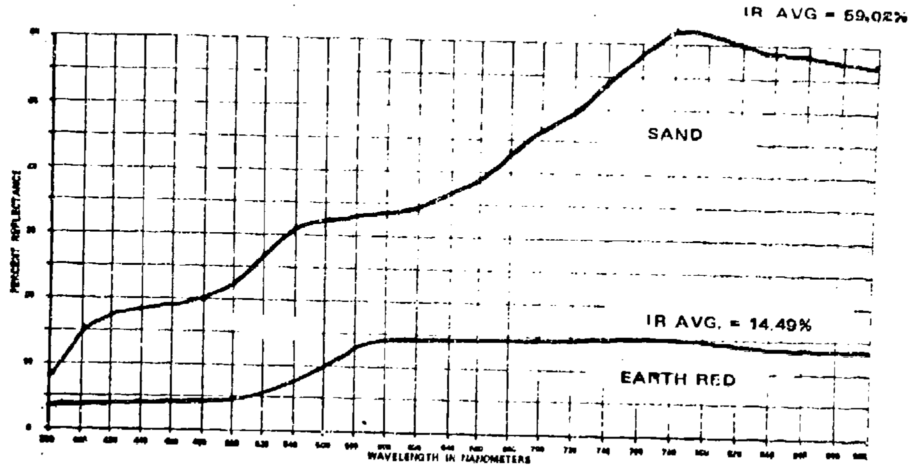


Figure 7 Earth Red and Sand Spectral Reflectance

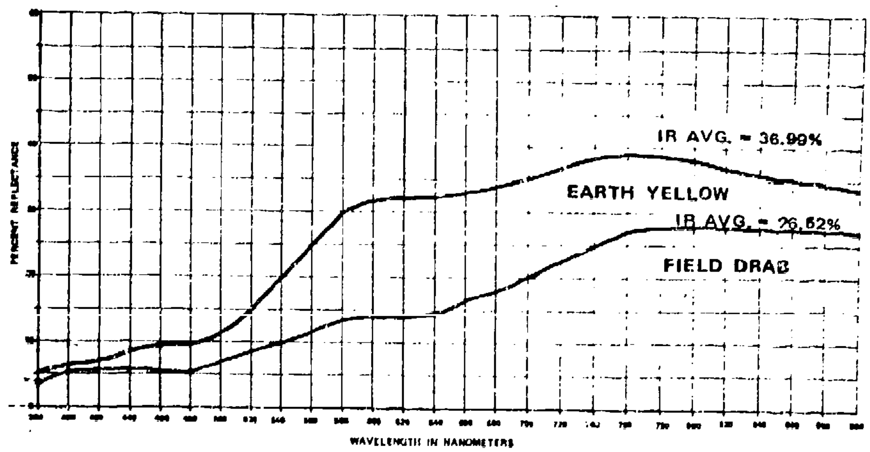


Figure 8 Earth Yellow and Field Drab Spectral Reflectances

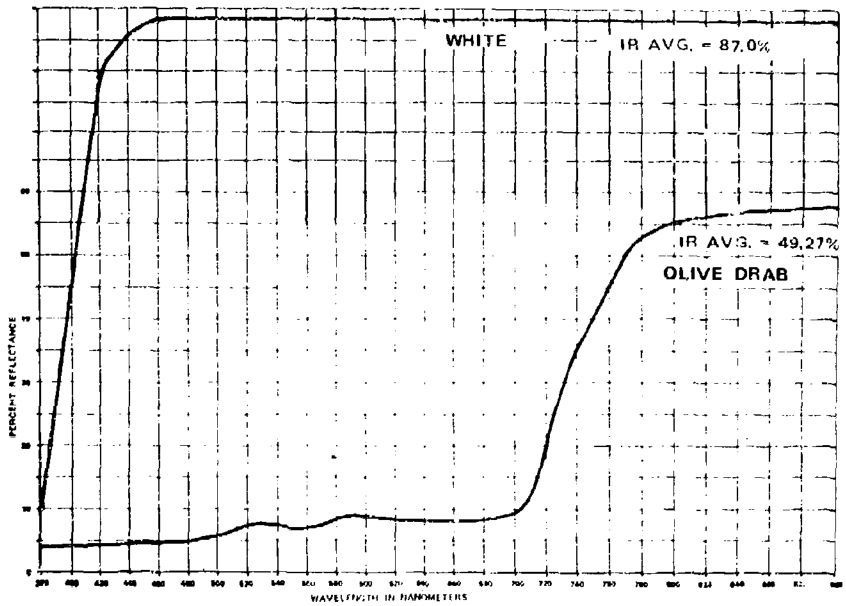


Figure 9 White and Olive Drab Spectral Reflectances

Color	"Y" Min	"Y" Max	Color	"Y" Min	"Y" Max
1	0.850	-	7	0.071	0.091
2	0.300	0.350	8	0.061	0.080
3	0.280	0.327	9	0.098	0.123
4	0.225	0.266	10	0.071	0.091
5	0.087	0.110	11	0.058	0.075
6	0.093	0.117	12	0.030	0.041

Figure 10 "Y" Tolerance for Camouflage Paint

TITLE	DATA SHEET 3006
CAMOUFLAGE PAINT, FOR PATTERN PAINTING	PAGE 11 OF 11

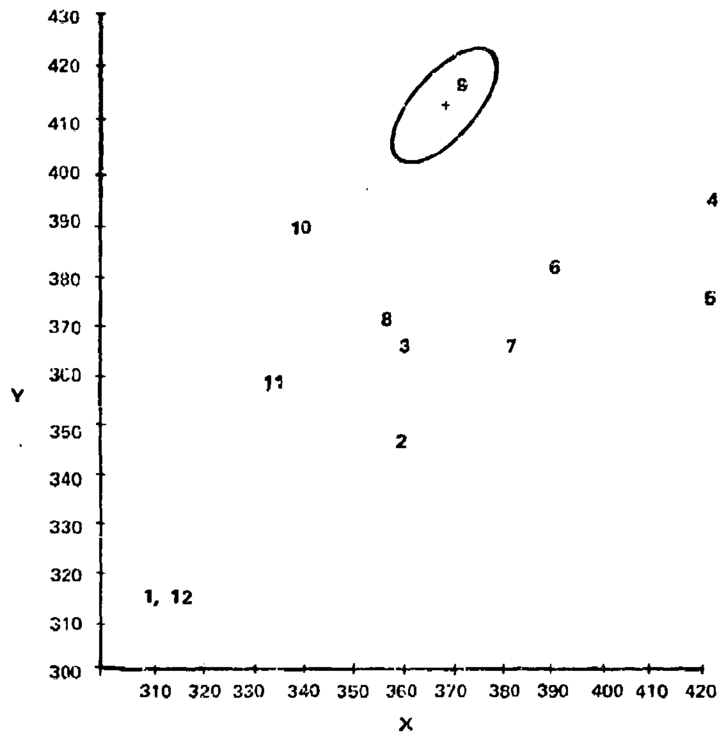


Figure 11 Chromaticity Diagram for Camouflage Paint

1 =	WHITE	7 =	EARTH BROWN
2 =	DESERT SAND	8 =	OLIVE DRAB
3 =	SAND	9 =	LIGHT GREEN
4 =	EARTH YELLOW	10 =	DARK GREEN
5 =	EARTH RED	11 =	FOREST GREEN
6 =	FIELD DRAB	12 =	BLACK

TITLE	DATA SHEET 3007
PAINT, ARCTIC, CAMOUFLAGE, REMOVABLE, MIL-P-52905	PAGE 1 OF 4

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

To minimize detection of objects by visual observation, photographic techniques, or by other sensors operating in the ultraviolet, visible, or near-infrared regions of the electromagnetic spectrum.

POTENTIAL APPLICATION:

This material is intended for use on items of military equipment deployed in snow covered areas (either total snow cover or partial, temporary snow conditions).

DESCRIPTION:

This is a camouflage white paint designed for use in snow covered environments. It can be used for complete painting of a vehicle or equipment deployed in areas of total snow cover or, in combination with other camouflage colors, for pattern painting where the snow cover is partial. The spectral properties and color values of the material are shown in the attached figures. The color tolerances are values determined by the CIE system. The chromaticity ellipse defines the 2.0 NBS units tolerance.

EXPERIENCE:

This material was developed to have in the inventory a quick reaction means of camouflaging field combat materiel, capable of being applied and removed by troops. It replaces the use of white wash which required the addition of salt for durability; salt is injurious to equipment. Experience to date has only been on a minor scale in Europe and Korea.

OTHER CONSIDERATIONS:

This is the only white paint in the Army supply system that offers ultraviolet (UV) protection. If UV is considered a threat for the particular application, then this material should be used in place of the white paint from MIL-P-13340C.

TITLE	DATA SHEET 3007
PAINT, ARCTIC, CAMOUFLAGE, REMOVABLE, MIL-P-42905	PAGE 2 OF 4

SEE DATA SHEETS:

3006, 3008, 3009, 3010

REFERENCES:

1. TC5-200, Camouflage Pattern Painting

2. Report number 2090, Camouflage Pattern Painting Report of USAMERDC's Camouflage Support Team to MASSTER, February 1974, Ft. Belvoir, Virginia.

3. TB43-0147, Color, Marking, and Camouflage Patterns used on Military Equipment Managed by USATROSCOM, December 1975.

4. TB746-95-1, Color, Marking, and Camouflage Pattern Painting for Armament Command Equipment, May 1976.

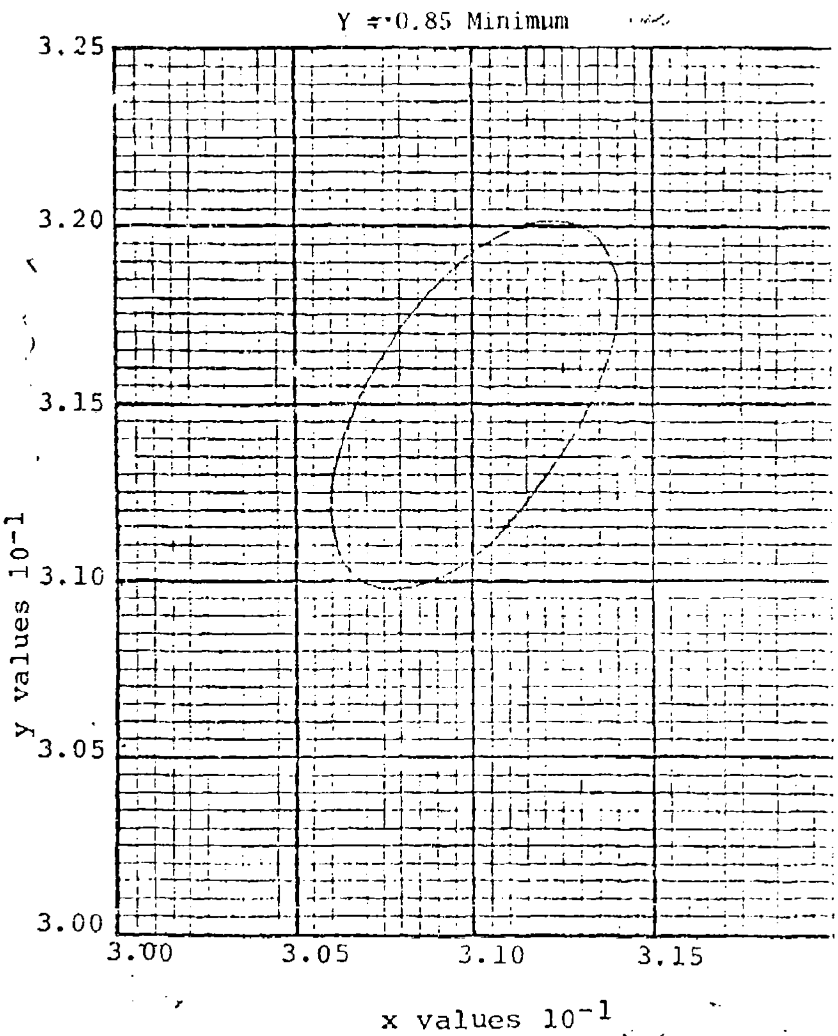
5. TB43-0118, Field Instructions for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelter, 19 December 1975.

6. Military Specification, MIL-P-13340C Paint, Water and Gasoline Thinnable, Camouflage.

7. AR 750-58, Painting, Camouflage Painting and Marking or Army Materiel.

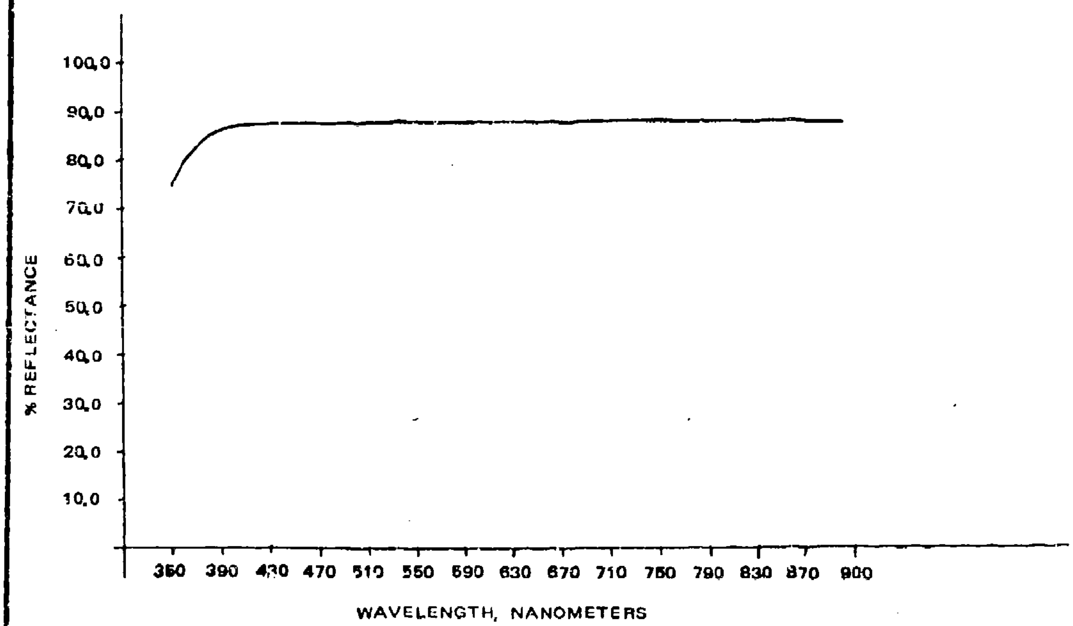
8. TM 43-0139, Painting Instructions for Field Use.

TITLE	DATA SHEET 3007
PAINT, ARCTIC, CAMOUFLAGE, REMOVABLE MIL-P-52905	PAGE 3 OF 4



COLOR TOLERANCES FOR ARCTIC WHITE PAINT, MIL-P-52905

TITLE	DATA SHEET 3007
PAINT, ARCTIC, CAMOUFLAGE, REMOVABLE, MIL-P-52905	PAGE 4 OF 4



TYPICAL SPECTRAL REFLECTANCE CURVE FOR REMOVABLE WHITE PAINT, MIL-P-52905

TITLE	DATA SHEET 3008
PAINT, CAMOUFLAGE, FOREST GREEN	PAGE 1 OF 3

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

To minimize detection of objects by visual observation or photographic techniques. Military objects possess characteristic signatures of color, shine, shape and shadow. This paint is designed to significantly reduce the color and shine signatures.

POTENTIAL APPLICATION:

This paint is designed for use as the original paint on materiel that is not destined for further camouflage, and as a common color component of pattern painting designs. It is also used as the original paint for equipment that will be pattern painted.

DESCRIPTION:

Seven different paints, formulated for specific properties, are available in this Forest Green color. A description of each follows:

MIL-E-52798A Enamel Alkyd Camouflage is primarily used as a field applied pattern paint but it can also be used as the Forest Green Base Coating on new equipment when the longer drying time of this materiel is not a factor.

MIL-C-46168A, Coating, Aliphatic Polyurethane, Low Reflective, Chemical Agent Resistant, Camouflage; is used for Pattern Painting in the field where chemical, biological and radiological (CBR) resistance is required.

MIL-E-52835A, Enamel, Modified Alkyd, Camouflage, Lusterless. This is used as a production line baked finish for mobility equipment. Used in place of baking version of TT-E-527.

MIL-L-52909, Lacquer, Acrylic, Camouflage. Used primarily as a production line paint on new equipment because of its quick dry and excellent durability. Can be applied in the field as the Missile Command is presently doing on Pershing Missiles.

MIL-L-52926, Lacquer, Hot Spray, Camouflage. Used strictly as a production line

TITLE	DATA SHEET 3008
PAINT, CAMOUFLAGE, FOREST GREEN	PAGE 2 OF 3

coating on new equipment. Applied primarily to vehicles and yields an especially hard finish. Use in place of MIL-L-11195.

MIL-E-52929, Enamel, Phenolic, Camouflage, Lusterless. Can be applied either on a production line or in the field. Will be applied to bridging because of its water resistance. Use in place of TT-E-522.

PROPOSED MILITARY SPECIFICATION

Enamel, Alkyd, Lusterless, Quick Drying Camouflage. For use as a fast dry finish coat on equipment which requires superior performance (better ultraviolet resistance).

PROPOSED MILITARY SPECIFICATION

Coating, Epoxy, Polyamide, Camouflage. For protection of areas exposed to chemicals and solvents and is intended for exterior use on weapon systems and other applications. Use in place of MIL-C-22750.

All seven paints possess color and spectral reflectance properties identical to the Forest Green described in Data Sheet 3006. Instructions for surface preparation, priming and painting can be found in the references cited.

EXPERIENCE:

The two paints with military specification numbers have been successfully used as described above.

The other five paints, without specification numbers assigned as yet, are new improved issues formulated to replace the older materials identified above.

OTHER CONSIDERATIONS:

Except for MIL-E-52198A and MIL-C-46168 these paints exist in only the Forest Green color, and consequently are not adequate by themselves for pattern painting.

SEE DATA SHEETS: 3006, 3007, 3009, 3010

TITLE	DATA SHEET 3008
PAINT, CAMOUFLAGE, FOREST GREEN	PAGE 3 OF 3

REFERENCES:

1. TC5-200, Camouflage Pattern Painting.

2. Report number 2090, Camouflage Pattern Painting Report of USAMERDC's Camouflage Support Team to MASSTER, February 1974, Ft. Belvoir, Virginia.

3. TB43-0147 Color, Marking, and Camouflage Patterns used on Military Equipment Managed by USATROSCOM, December 1975.

4. TB746-95-1 Color, Marking, and Camouflage Pattern Painting for Armament Command Equipment, May 1976.

5. TB43-0118, Field Instructions for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelters, 19 December 1975.

6. Report number 2177, Spectral Reflectance Evaluation of Camouflage Detection Photography, USAMERADCOM, May 1976, Ft. Belvoir, Virginia.

7. Military Specification, MIL-E-52798A(ME), 21 May 1976, Enamel, Alkyd, Camouflage.

8. Military Specification, MIL-P-13340C Paint, Water and Gasoline Thinnable, Camouflage.

9. Military Specification, MIL-C-46168A Coating, Aliphatic, Polyurethane, Low Reflective, Chemical Agent Resistant, Camouflage.

10. AR 750-58, Painting Camouflage Painting and Marking of Army Materiel.

11. TM 43-0139, Painting Instructions for Field Use.

12. MIL-E-52835A, Enamel, Modified, Alkyd, Camouflage Lusterless.

13. MIL-L-52909 Laquer, Acrylic, Camouflage.

TITLE	DATA SHEET 3009
SOLAR AND HEAT REFLECTING CAMOUFLAGE PAINT	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

This is an external surface paint designed to reduce the internal temperature of equipment and provide camouflage coloration.

POTENTIAL APPLICATION:

This material is planned for use on equipment to reduce the internal temperatures for reasons of personnel comfort or to protect electronic devices, etc., that malfunction under elevated temperature conditions.

DESCRIPTION:

Current development of this paint is toward incorporation of the dark green and forest green camouflage colors (see Data Sheet 3006 for a description of the color and spectral requirements for forest green and dark green camouflage colors). One difference is that this material will have a higher minimum on the near-infrared region, probably 55-66%, as opposed to the 42% minimum described in Data Sheet 3006. This is necessary to achieve the high level of solar reflectance.

EXPERIENCE:

This is a new paint designed for use on missiles, cargo vans, shelters, etc.

REFERENCES:

1. TC5-200, Camouflage Pattern Painting.

2. Report number 2090, Camouflage Pattern Painting Report of USAMERDC's Camouflage Support Team to MASSTER, February 1974, Ft. Belvoir, Virginia.

3. TB43-0147, Color, Marking, and Camouflage Patterns Used on Military Equipment Managed by USATROSCOM, December 1975.

4. TB546-95-1, Color, Marking and Camouflage Pattern Painting for Armament Command Equipment, May 1976.

TITLE	DATA SHEET 3009
SOLAR AND HEAT REFLECTING CAMOUFLAGE PAINT	PAGE 2 OF 2

REFERENCES (CONTINUED)

5. TB43-0118, Field Instructions for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelter, 19 December 1975.

6. Report number 2177, Spectral Reflectance Evaluation of Camouflage Detection Photography, USAMERADCOM, May 1976, Ft. Belvoir, Virginia.

7. Military Specification, MIL-E-52798 (ME), 21 May 1976, Enamel, Alkyd, Camouflage.

8. Military Specification, MIL-P-13340C, Paint, Water and Gasoline Thinnable, Camouflage.

9. Military Specification, MIL-C-46168A, Coating, Aliphatic Polyurethane, Low Reflective, Chemical Agent Resistant, Camouflage.

10. AR 750-58, Painting, Camouflage Painting and Marking of Army Materiel.

11. TM 43-0139, Painting Instructions for Field Use.

TITLE	DATA SHEET 3010
LOW REFLECTIVE ACRYLIC LACQUER, MIL-L-46159A	PAGE 1 OF 4

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

The purpose of this material is to impart total diffuse reflectance to equipment surfaces, thereby reducing the attention-getting "glint" from an object.

POTENTIAL APPLICATION:

Primarily to mobile, tactical items of military equipment.

DESCRIPTION:

This paint is formulated to minimize specular reflection of painted surfaces, and is achieved to an even greater degree than the low reflective paint specified by MIL-E-52798A. The following figure compares the specular reflectance of this material to MIL-E-52798A forest green and color number 34087 of Federal Standard 595A.

MIL-L-46159A is available in two colors, aircraft green and black. The spectral reflectance curves of the two colors are shown in the following graphs.

EXPERIENCE:

This material has been utilized on Army helicopters; it is a green color for external paint, and black for the interior surfaces of the cockpit. The paint was specially developed to counter the threat of the Russian STRELLA missile, which is a heat seeking missile that utilizes a lead sulfide (PbS) sensor.

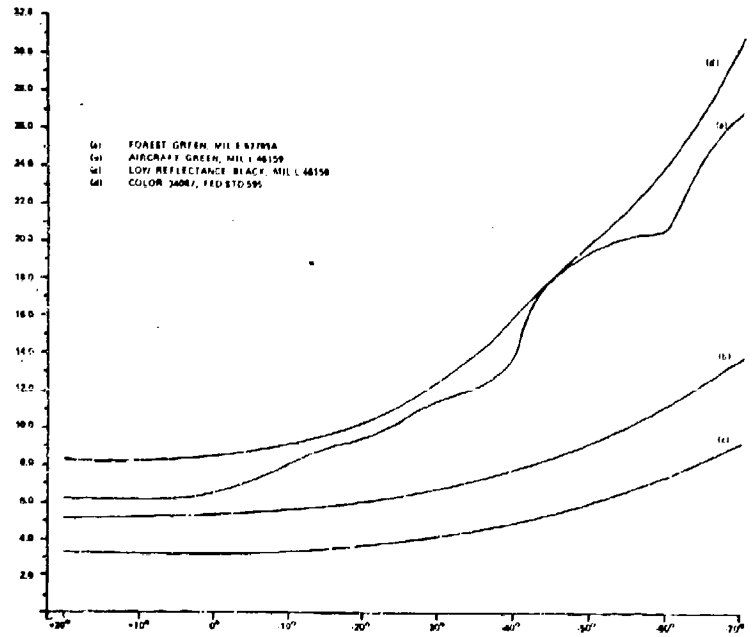
OTHER CONSIDERATIONS:

A smooth, low reflective finish currently under development to replace MIL-C-19538, may be used for Army fixed wing aircraft.

TITLE

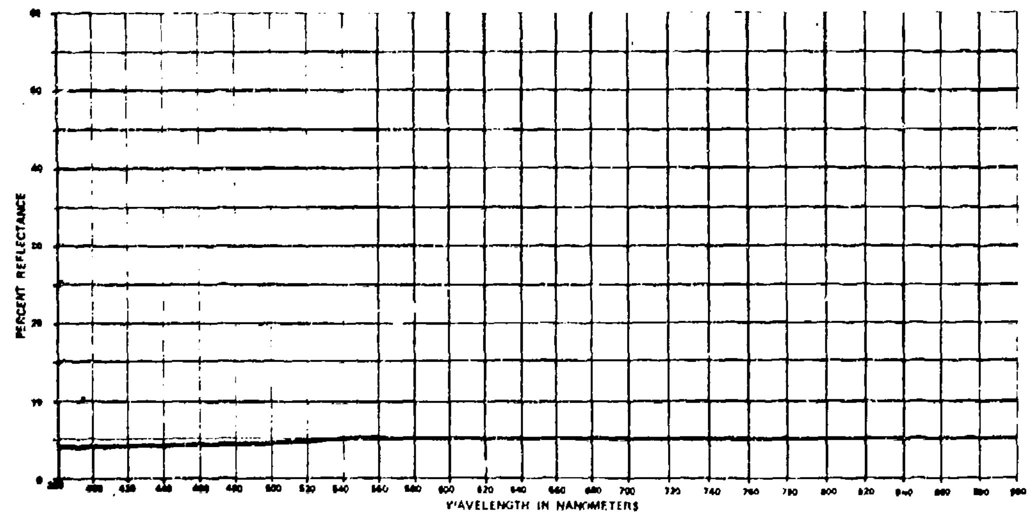
LOW REFLECTIVE ACRYLIC LACQUER, MIL-L-46159A

DATA SHEET 3010

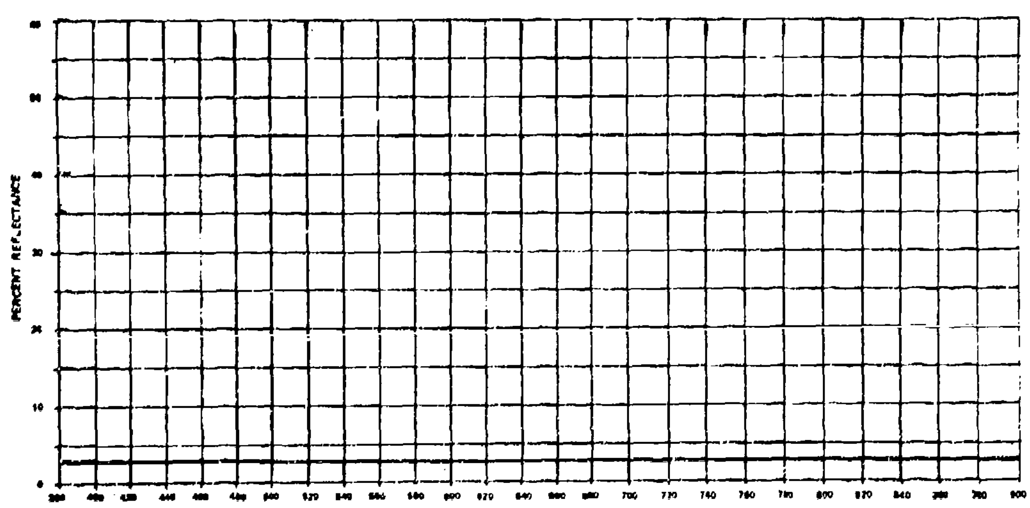


SPECULAR REFLECTANCE (45° VIEWING) OF SELECTED CAMOUFLAGE PAINTS

TITLE	DATA SHEET 3010
LOW REFLECTIVE ACRYLIC LACQUER, MIL-L-46159A	PAGE 3 OF 4



AIRCRAFT GREEN



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TITLE	DATA SHEET 3010
LOW REFLECTIVE ACRYLIC LACQUER, MIL-L-46159A	PAGE 4 OF 4

SEE DATA SHEETS: 3006, 3007, 3008, 3009

REFERENCES:

1. TC5-200, Camouflage Pattern Painting.
2. Report number 2090, Camouflage Pattern Painting Report of USAMERDC's Camouflage Support Team to MASSTER, February 1974, Ft. Belvoir, Virginia.
3. TB43-0147, Color, Marking, and Camouflage Patterns used on Military Equipment Managed by USATROSCOM, December 1975.
4. TB746-95-1, Color, Marking and Camouflage Pattern Painting for Armament Command Equipment, May 1976.
5. TB43-0118, Field Instructions for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelters, 19 December 1975.
6. Report number 2177, Spectral Reflectance Evaluation of Camouflage Detection Photography, USAMERADCOM, May 1976, Ft. Belvoir, Virginia.
7. Military Specification, MIL-E-52798(ME), 21 May 1976, Enamel, Alkyd, Camouflage.
8. Military Specification, MIL-P-13340C, Paint, Water and Gasoline Thinnable, Camouflage.
9. Military Specification, MIL-C-46168A, Coating, Aliphatic Polyurethane, Low Reflective, Chemical Agent Resistant Camouflage.
10. AR 750-58, Painting, Camouflage Painting and Marking of Army Materiel
11. TM 43-0139, Painting Instructions for Field Use.

TITLE	DATA SHEET 3011
CAMOUFLAGE CLOTH	PAGE 1 OF 12

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

Camouflage cloth is useful for hiding, blending, disguising, or otherwise concealing or covering items of military equipment. Detection by an observer can be denied because the camouflaged item is a close copy of the natural surroundings with respect to color appearance and properties in certain other portions of the electromagnetic spectrum. In those cases where detection is not denied this material can retard identification of the equipment by obscuring its size, shape or other peculiar characteristics.

POTENTIAL APPLICATION:

This material is complementary to the lightweight screening systems (See Materiel Data Sheet 2000), in that it is most suited for: camouflage small items of equipment; for concealing foxholes, tracks, etc.; or for adding to a screen deployment where small, finishing touches are needed.

DESCRIPTION:

Camouflage cloth is a lightweight, vinyl coated nylon material with the physical properties shown in Table III: Both sides of the nylon are coated with flexible vinyl films, giving the choice of color combinations shown in Table I. Colors 1,2,3, and 6 are formulated for utilization in woodland environments during spring and summer. In addition to the visual color which approximates natural foliage, colors 1 and 2 have the characteristic shape of the spectrophotometric curve of chlorophyll in the red and near-infrared (NIR) spectral regions (see figure 2). This relatively large ratio of near-infrared to red reflectance defeats detection by color infrared (camouflage detection) photography.

Colors 1,3,5, and 7 are designated fall and winter colors for woodland areas. Color number 1 is included to allow for evergreen foliage and, therefore, should be utilized proportionally as the natural surroundings dictate.

A mixture of colors 5,9,10,and 11 is the general formula for reproducing a tan shade of desert environment; colors 9,10, and 12 yield a grayer mixture. Special restraint should be exercised in the utilization of colors 8 and 11, since these occur infrequently in desert environments.

TITLE	DATA SHEET 3011
CAMOUFLAGE CLOTH	PAGE 2 OF 12

The arctic camouflage cloth is designed for use in totally snow-covered environments or in partial snow where the snow covering is partially broken by evergreen foliage, rocks, earth, tree trunks, stumps, etc.

The CIE (International Commission on Illumination) system of color notation is used to quantitatively define the camouflage colors. The chromaticity coordiantes, x and y, of each are shown in Figure 1. The usual specification for color tolerance is the locus of points 2.0 NBS units from the target value. This locus takes the form of an ellipse. The 2 NBS ellipse for the dark green color is shown in Figure 1. Ellipses (not shown) for the other colors are centered around the indicated target values and are the same order of magnitude in size and have approximately the same orientation.

The third coordinate of CIE color notation is the apparent reflectance function, Y, sometimes called brightness or lightness. This function is a measure of total visible light reflected from a sample surface irrespective of hue or saturation. (A perfectly white, perfectly diffuse surface theoretically gives Y+100%). The apparent reflectance specifications for camouflage cloth colors are given in Table II.

Also shown in Table II are the average NIR reflectance specifications for camouflage cloth colors. In addition to the specially shaped spectrophotometric curves mentioned above for colors 1 and 2, all the colors have been formulated to give NIR reflectances of the same magnitude as the natural environments where they are designed to be used.

Camouflage cloth can be used in either incised or flatstock forms. Small incising, shown in Figure 5 is more commonly used and provides blade-like texture. Camouflage cloth combinations 1/1 and 6/7 are usually given the larger incising (Figure 6) which provides a leaf-like texture.

Camouflage cloth contains radar scattering elements which deny discovery or identification of military equipment by microwave sensors. The cloth attenuates the microwave return to a level approximating natural background return. The radar reflection and transmission properties of incised and flatstock cloth are shown in Figures 3 and 4. Radar transparent camouflage cloth is also manufactured.

Vinyl Coated Nylon Garnish Materiel must be used. This type of radar transparent cloth must be used for camouflaging friendly radar equipment, otherwise the equipment would be rendered ineffective.

All the above-discussed properties must be considered when utilizing this material for a camouflage application. Personal judgement will be involved in selecting the colors of cloth to use and its physical arrangement (geometry) on and about the equipment item. As a general rule, more than one color is required, usually three to five, to achieve the desired innocuous appearance. Straight lines and noticeable planes must be avoided when attaching the cloth to the equipment. When flatstock is used, special care should be taken to incorporate folds, bulges, shadows and other irregularities to minimize straight lines and planar surfaces. Incised cloth usually gives more effective camouflage because a degree of irregularity, depth, and shadow, is already present.

Blending the camouflage with natural foliage and landscape increases the effectiveness. A simple example is that it is easier to hide a weapon in a forest than in an open field. Using the shadow side of the base of a hill is more effective than the exposed top of that hill.

To achieve the natural appearance of depth and shadow, and to fully utilize the radar scattering properties of camouflage cloth, a separation distance of at least one foot should be maintained between the cloth and the item that is being camouflaged.

TITLE	DATA SHEET 3011
CAMOUFLAGE CLOTH	PAGE 4 OF 12

Table I

VISIBLE AND NEAR INFRARED REFLECTANCE RANGES OF CAMOUFLAGE CLOTH COLORS

Color Name	Color Number	Visible Brightness C.I.E. "Y" Apparent Reflectance, %	Average* Near Infrared Reflectance, %
Dark Green	1	7.0 - 8.5	65 max.
Light Green	2	9.4 - 10.8	65 max.
Khaki	3	21.0 - 23.0	40 - 75
Olive	4	9.7 - 11.3	25 - 55
Tan	5	21.0 - 23.0	35 - 55
Forest Green	6	5.8 - 7.2	25 - 35
Brown	7	10.2 - 11.8	20 - 25
Straw	8	27.8 - 30.7	35 - 60
Desert Khaki	9	23.9 - 26.7	25 - 60
Desert Tan	10	33.3 - 36.4	35 - 60
Russet	11	16.9 - 19.1	20 - 40
Light Brown	12	18.7 - 21.3	25 - 45
White	13	85.0 - 100	85 - 100

*Wavelengths, in nanometers, used for calculating average near infrared reflectance:

714	751	777	807	836
725	756	783	811	842
730	760	787	816	848
737	764	793	821	855
742	769	797	826	862
747	773	802	831	873

Table II

CAMOUFLAGE CLOTH COLOR COMBINATIONS

Cloth	Color Numbers*
WOODLAND CLASS	
Dark Green/Dark Green	1/1
Light Green/Khaki	2/3
Olive/Tan	4/5
Forest Green/Brown	6/7
DESERT CLASS	
Straw/Straw	8/8
Khaki/Khaki	9/9
Tan/Tan	10/10
Tan/Khaki	10/9
Medium Tan/Khaki	5/9
Russet/Light Brown	11/12
WINTER (ARCTIC) CLASS	
White/White	13/13
Forest Green/White	6/13
Tan/White	5/13

*For reference to chromaticity diagrams, spectrophotometric curves, etc.

Table III

PHYSICAL PROPERTIES OF CAMOUFLAGE CLOTH

Property	Typical Values	Test Method/Comments
Unit Weight	7-8 ounces/square yd.	-
Water Absorption	15% weight increase	4 hour or more immersion
Flexibility	Adequate to - 40°F	FTMS 191, Method 5204
Breaking Strength	40 pounds	ASTM D-1682, Grab Method
Flame Resistance	Self-extinguishing	-
Specular Gloss	1.0 gloss units at 85°	-
	2.0 gloss units at 60°	-
Fungus Resistance	Does not support fungus growth	Test organism is aspergillus niger; FTMS 191, Method 5136
Tear Strength	6 pounds	Trapezoid method

*Each property is tested initially, and selected properties are tested after environmental and other exposures, such as: accelerated weathering, accelerated aging, accelerated fading, water immersion, petroleum immersion, salt fog exposure. humidity exposure, and fungus exposure. A complete description of test procedures and specifications is given in MIL-C-52771(ME).

TITLE	DATA SHEET 3011
CAMOUFLAGE CLOTH	PAGE 7 OF 12

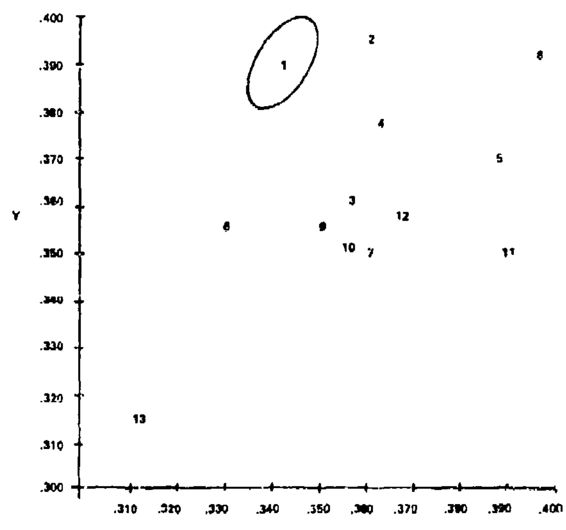

FIGURE 1

C.I.E. Chromaticity Coordinates of Camouflage Cloth Colors

TITLE	DATA SHEET 3011
CAMOUFLAGE CLOTH	PAGE 8 OF 12

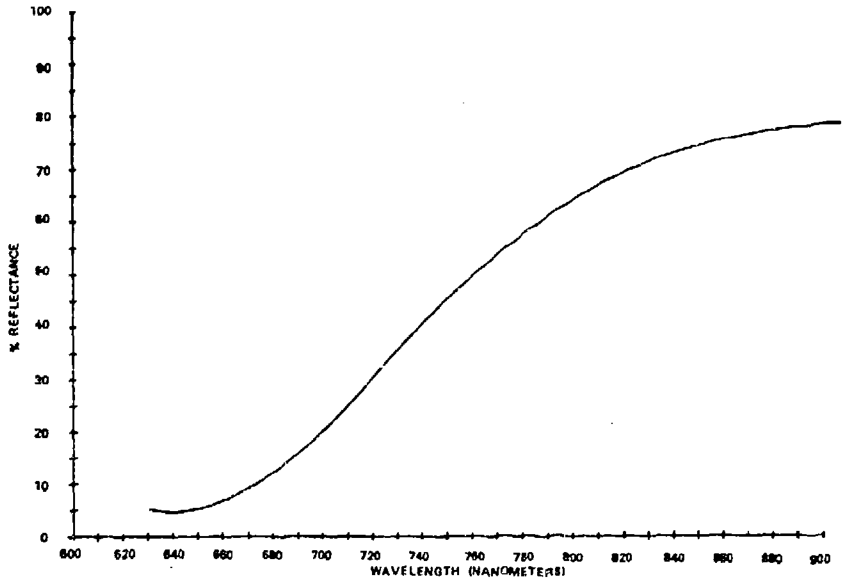

FIGURE 2

Red and Near Infrared Spectrophotometric Curve with Shape Characteristic of Chlorophyll, Typical Values for Dark Green and Light Green Colors of Camouflage Cloth

TITLE	DATA SHEET 3011
CAMOUFLAGE CLOTH	PAGE 9 OF 12

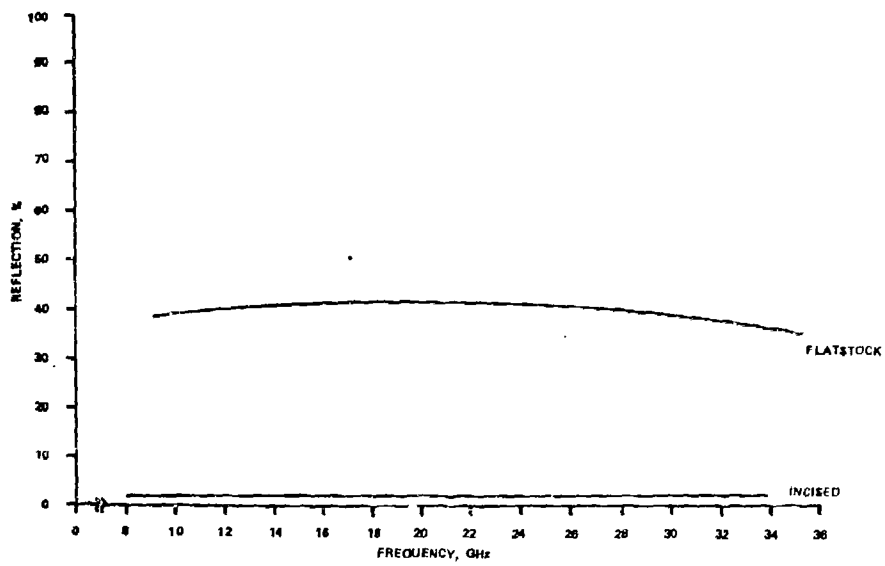

FIGURE 3

Reflection vs Frequency of Incised and Flatstock Camouflage Cloth

TITLE	DATA SHEET 3011
CAMOUFLAGE CLOTH	PAGE 10 OF 12

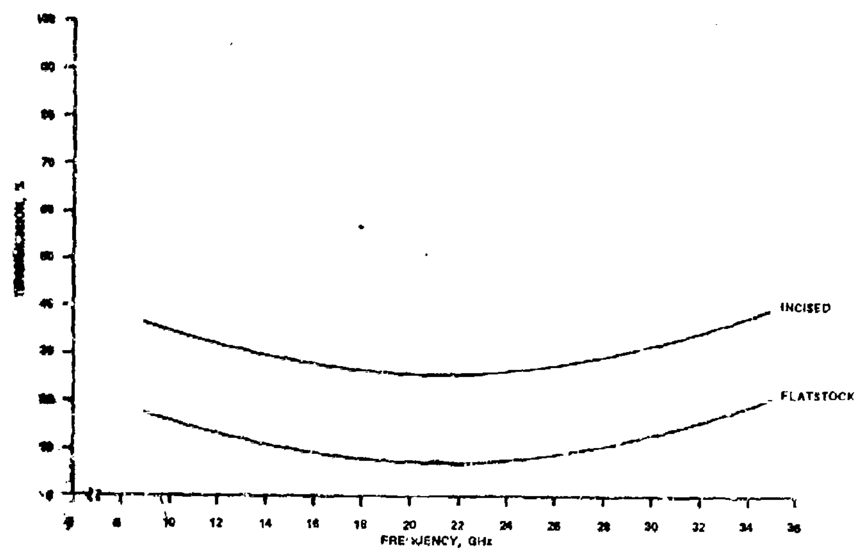

FIGURE 4

Transmission vs Frequency of Incised and Flatstock Camouflage Cloth

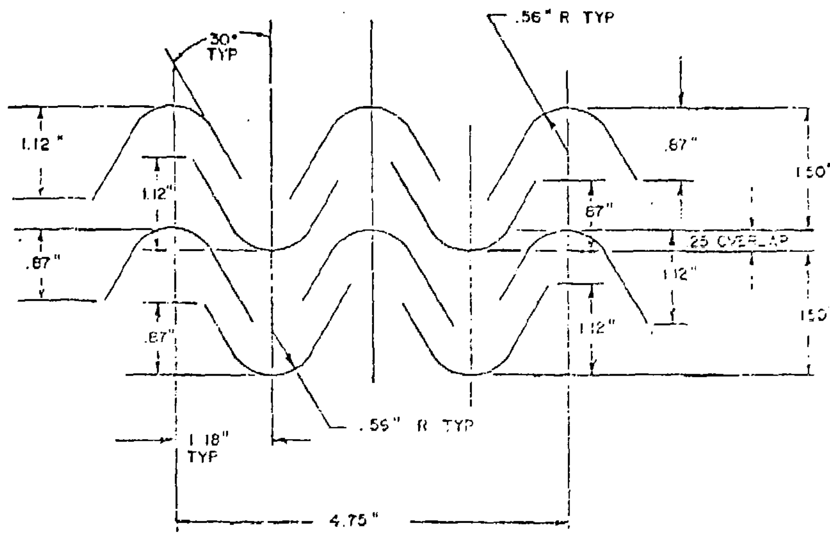

FIGURE 5

Small Incising

TITLE CAMOUFLAGE CLOTH	DATA SHEET 3011
	PAGE 12 OF 12

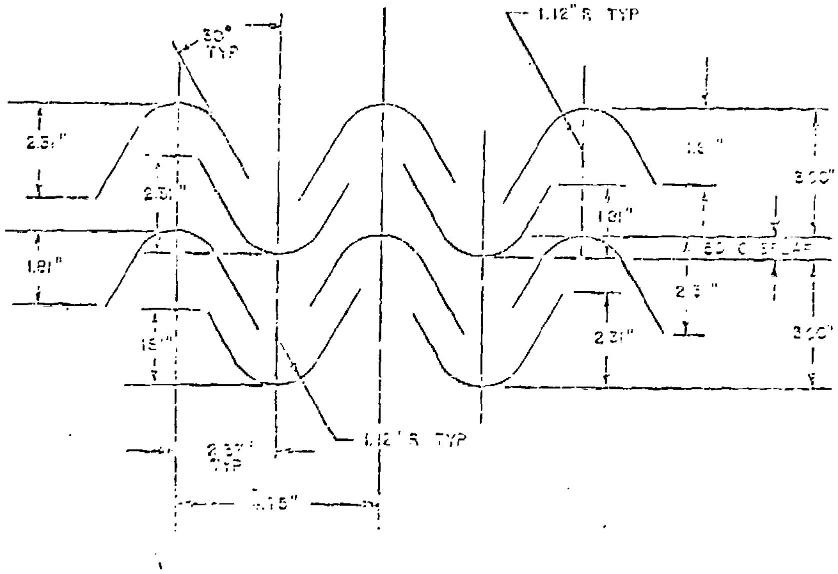

FIGURE 6

Large Incising

SEE DATA SHEETS: 2000

TITLE	DATA SHEET 3012
URETHANE FOAM	PAGE 1 OF 2

CAMOUFLAGE TECHNIQUE ☐ CAMOUFLAGE MATERIEL ☐ CAMOUFLAGE MATERIAL ☒

PURPOSE:

Urethane foam can be utilized to disrupt a target's signature or for the construction of dummy fortifications and decoys.

POTENTIAL APPLICATION:

The material can be used on military equipment to disguise the object's signature or to create decoy objects.

DESCRIPTION:

The rigid, closed-cell polyurethane foam is formed from a pressurized two-part dispensing system (see reference 1). The foam expands when it comes in contact with air and hardens in about five minutes.

For construction of decoy objects one simple method utilizes the real object (archetype) as a mold. The archetype is covered with plastic sheets which are then sprayed with the foam. As the foam hardens, the shell that is formed is the decoy. Pigments are added to the urethane liquids, before spraying, to achieve the desired color.

Foam can be sprayed to build up selected areas on equipment, thereby disrupting the object's shape and signature.

EXPERIENCE:

Urethane foam shells of a 55-gallon drum and of a simulated bunker were formed by first covering the drum and bunker with plastic sheets and then spraying with the foam.

An M151 vehicle that was covered with plastic sheeting was also sprayed with the foam.

OTHER CONSIDERATIONS:

The dispensing equipment, as currently configured, is extremely complex and would be an unacceptable burden on logistics systems. To possess military potential, the equipment must be further refined and simplified to achieve operational reliability and a capability to dispense multipigmented urethane foam from a single unit.

TITLE	DATA SHEET 3012
URETHANE FOAM	PAGE 2 OF 2

REFERENCES:

1. Camouflage Evaluation Report (Phase I), MASSTER TEST REPORT No. FM 153, 21 January 1974.

5.9 EXAMPLE PROBLEM

An example illustrating the material discussed in this section is contained in Appendix A of this Guide.

SECTION 6

CAMOUFLAGE EVALUATION AND TESTING

This section of the Guide is concerned with the tests and evaluations of those qualities of a camouflage treatment which relate to the perceptibility of the item and to the compatibility of the treatment with the operation of the item. The perceptibility of an item, with or without a camouflage treatment, is its susceptibility to being detected, recognized, identified, or located by a remote sensing system. In this context, the remote sensing system includes the associated components for reducing, analyzing and interpreting the sensor data.

The terms *test* and *evaluation* will be used herein as they are defined in Reference 1.

> A test is a process by which data are accumulated to serve as a basis for assessing the degree that a system meets, exceeds, or fails to meet the technical or operational properties ascribed to the system.
>
> An evaluation is a subjective determination, accomplished jointly by the several major subordinate commands, of the utility, i.e., the military value of a hardware item/system -- real or conceptual to the user.

The perceptibility required of an item incorporating a specific camouflage treatment depends upon the intent of the treatment. Reduced perceptibility is required of those treatments which attempt to conceal an item/system by hiding and blending; whereas enhanced perceptibility is required for a decoy to be effective. The perceptibility of a disguise should be near that of the object or background being represented; the perceptibility required depends upon the level of deception desired.

The purpose of camouflage testing and evaluation is to obtain answers to four important questions:

1. What are the characteristics of nature and of the background that need to be mimicked by the camouflage?

2. What is the perceptibility (i.e., performance) of a specific camouflage treatment?

3. What is the military worth of the perceptibility achieved by the camouflage?

4. What specifications must the materials and the construction of the camouflage meet in manufacture in order to produce the intended perceptibility?

The concepts used to obtain answers to these questions are discussed in the remainder of this Section. The specifics of how to test and evaluate camouflage may be found in the references. Provisions should be made at the beginning of a camouflage program for simulations, modeling and field testing which will be needed for verification and/or evaluation of camouflage performances.

While the Developer maintains overall responsibility for the testing of the camouflage treatment of his item/system, the testing may be accomplished with assistance from MERADCOM. This assistance could range from minor consultation using MERADCOM in-house funding to full scale participation utilizing Developer funding. The collection of generalized camouflage data is primarily a MERADCOM responsibility and would be available to any Developer upon request.

6.1 TYPES OF CAMOUFLAGE TESTS AND EVALUATION

6.1.1 Background Testing

Since detection cues consist of contrasts between perceptible qualities of the item and of its background, measurement of these qualities of the backgound indicate the direction of camouflage material and design development. For example, the characteristic color of some piece of terrain suggests the color of coatings for military equipment operating in that terrain. The reflectance of live foliage in the near-infrared region drives the requirements for near-infrared reflectance of green coatings. The near-ultraviolet reflectance of snow dictates the desired reflectance of white coatings in the near-ultraviolet region. The radar clutter and cross section density of terrain set desirable goals for the radar cross section of items required to blend into the terrain.

There are two approaches to obtaining such data on backgrounds. The first is to select samples and measure their properties in a laboratory. The second is to take instruments to the field to examine some larger resolution cell and thus average the variability found in nature. The first approach has the advantage of complete control, but suffers from errors resulting from the combining of individual measurements into what is to be expected in the real world. The spectral reflectance of a selection of leaves Figure 6-1, (Reference 2) does not define the precise effects produced by a forest, but it does provide indications of the relative absorption and reflection of energy by the forest.

The second means provides data which integrates all the variables, but lacks comparability of one observation to another due to the constantly changing environment. Examples of laboratory-determined and field-determined data on background are furnished in References 3 and 4.

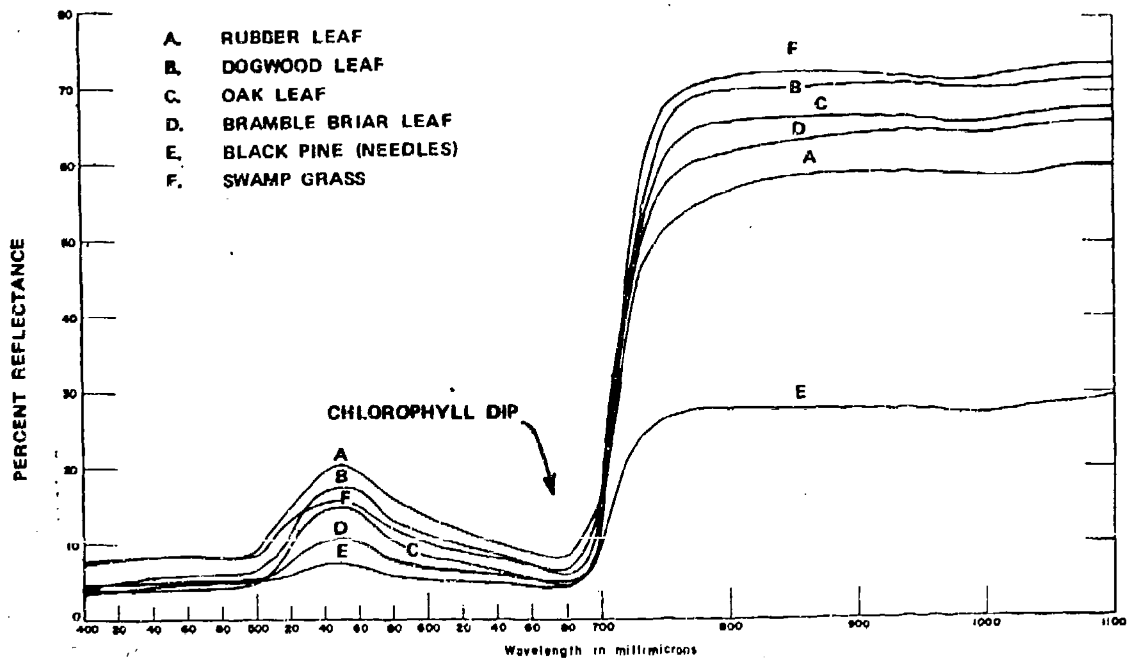

Figure 6-1 Spectrophotometric Curves of Green Leaves

6.1.2 Perceptibility Testing

6.1.2.1 General

Camouflage performance, i.e., perceptibility is measured in terms of measures of performance (MOP); the expected outcome of an encounter between a camouflaged item and a remote sensor system in a given en-

vironment. Examples of MOP include: acquisition rate, probability of detection as a function of range and search time, and location error to range ratio. In Figure 6-2, the measure of performance of two levels of camouflage of an M-60A1 tank is the range dependent probability of detection. The difference between the two MOP shown is an indication of the performance improvement caused by the additional camouflage. The improved performance is the reduction in the range at which detection will occur with a given frequency or probability.

The measures of performance selected and the performance test data obtained must be faithful to the needs and intent of the Military Worth Analysis if that analysis is to have validity. There are numerous ways to judge camouflage, but only a few are useful in questions of worth. It is in this area that difficulties in camouflage testing are experienced. The factors affecting the results of a set of observations relative to camouflage are numerous and often not recognized by those evaluating the data. False conclusions based upon unwarranted extensions of the specific outcome of a few trials must be guarded against. This is especially true in regard to the camouflage methods of hiding and blending because lighting, background, atmosphere, and a host of other conditions are constantly changing throughout a series of trials and often during one set of observations.

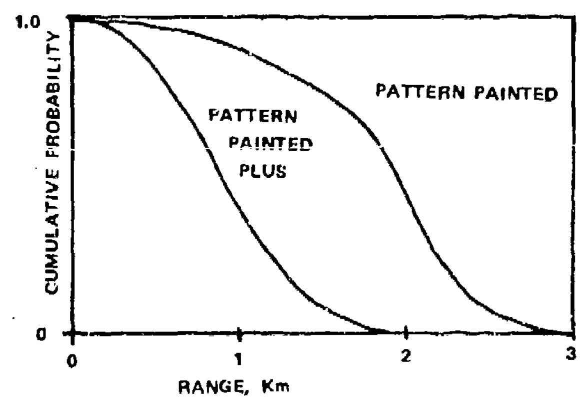

Figure 6-2 Unaided Eye Detection of M60A1 Tank (Ref. 5)

6.1.2.2 Types of Perceptibility Tests

The four types of camouflage perceptibility tests in common use are, in order of increasing cost: simulation, scale modeling, analytical models, and field trials. The main features of all camouflage perceptibility tests are the creation of a realistic situation, methodical conduct of the test, measurement and documentation of all critical test variables, and the statistical design and analysis of the test. Specific considerations for the conduct of a camouflage perceptibility test are furnished in Section 6.2.1 of this Guide.

Of the four types of perceptibility tests, field trials are both the most realistic and the most expensive. The high costs of field trials result from the logistics, coordination, and replication required. Field trials are, therefore, often restricted to final proof tests of completed camouflage treatments and are conducted in conjunction with other tests of the item/system under consideration. References 5, 6, and 7 contain examples of camouflage field trials.

The least developed type of perceptibility test is the analytical model, although it offers the greatest potential. When developed, a wide variety of designs may be tested rapidly. There are presently two major limitations to the usefulness of these models or computer programs: the detection and acquisition processes are not yet well defined and, therefore, imperfectly modeled; and only the gross features and characteristics of the camouflaged target are modeled. References 8 and 9 provide detailed information on the more capable of these models together with a review of similar models. One of the models, MARSAM II, calculates probabilities of detection, recognition, and identification given the following input characteristics of the target, background, weather, and sensors:

Target-Element Characteristics

Length, width, height
Radar cross section
Hot-spot temperature and area
Reflectance
Emissivity
Density of confusing objects
Temperature difference between element and background

Background or Environment Characteristics

Photo/Visual reflectivity
Radar cross section
Emissivity
Terrain masking data

Weather-Environment Characteristics

Height of each atmospheric layer in a layered atmosphere
Absolute humidity in each layer
Extinction coefficient for each layer
Ground illumination (as a function of solar altitude for day-direct lighting)
Cumulative one-way radar attenuation factors (as a function of wavelength)
Rates and extent of rain and/or snow
Additional atmospheric characteristics for particular sensor types (H_2O and CO_2 attenuation data for IR sensors and turbulence data for camera sensors are examples).

Sensor System Characteristics

Sensor Systems	Subsystems
Photographic	Sensor Lens

Sensor Systems (Contd.)	Subsystems (Contd.)
Photographic (Contd.)	Filter Film
Television (TV)	Sensor Lens Display
Active TV	Sensor Lens Display
Visual Observer	Sensor
Vertical Infrared (VIR)	Sensor Display of film
Forward-Looking Infrared (FLIR)	Sensor
Side-Looking Airborne Radar (SLAR)	Sensor Display (MTI only)
Forward-Looking Radar (FLR)	Sensor Display

Scale modeling consists of viewing miniature physical models against scaled backgrounds. This type of modeling is most useful in determining the perceptibility reductions produced by contrast reduction and configuration changes. Care must be taken to consider atmospheric and scaling effects.

A relationship exists between target surface areas and observation ranges. To illustrate, two fabrics, burlap and shrimp netting, placed side by side do not have the same appearance. Under very carefully controlled conditions, however, these two fabrics of different weaves and textures can be made to have a similar appearance by increasing the area of the shrimp netting and viewing it at a greater distance such that it appears to be the same size as the burlap. It is apparent from this example that a small square of burlap viewed at close range does not have the same appearance as a large square of the same fabric viewed at a greater range. Recognizing that scaling problems exist and are usually a function of textural differences will help to resolve these problems. Different materials and design are often required in the model to achieve the same effect produced by the full scale item. This type of modeling is not restricted to the optical region but is possible wherever a sensor can be modeled in scale.

There are several elaborate facilities in the U.S. with terrain models suitable for camouflage testing. Some of these are listed in References 10 and 11 and in Section 6.6.3 of this Guide. An example of scale modeling outside the visual region is the Camouflage Laboratory's 100-GHz Radar Cross Section Measurement and Diagnostic Imaging Facility used to scale-down target dimensions for analysis of target returns for threat frequencies

below 16 GHz. Other scale and microwave band combinations are possible. Reference 12 discribes the use of this equipment.

Simulations are most useful in early screening of proposed camouflage designs where an evaluation and interpretation of what is observed is desired. For example, visual simulators produce a picture by projecting images from one or more sources or by displaying a sequence of electronically generated scan lines. Versatility is achieved in these systems by the technical ability to embed images of the camouflaged item in the background scene. References 10 and 11 review the present state-of-the-art of simulators and their use in camouflage evaluation. Some facilities are listed in Section 6.3 of this Guide.

6.1.2.3 Existing Perceptibility Test Methodologies

References 13 through 17 are the first of a series of Camouflage Test Methodologies being compiled by USATECOM. These Methodologies review the underlying theory, previous tests, present capabilities, and the analyses associated with the testing of infrared, magnetic, radar, seismic, and sonic camouflage. This series is to include a Methodology for visual camouflage also.

6.1.3 Military Worth Evaluation

The military worth of camouflage is its effect on battle outcome. It is the degree to which the ability of a force to perform its mission is improved by the introduction of camouflage into the force. Military worth should be distinguished from performance, which is the degree to which a particular camouflage treatment accomplishes its assigned task. Military worth is a force attribute; performance is an attribute of a particular camouflage treatment.

The ability of a force to accomplish its mission is characterized by measures of effectiveness (MOE) which are quantified within certain confidence levels, and by intangibles such as leadership and morale. Examples of MOE include: rate of advance, blue/red casualties, and time to mission completion. The military worth of the camouflage to a force is measured by the change in the MOE from some base case, most often the uncamouflaged condition of the item/system.

Analyses of military worth requires selection of a combat scenario, an analytical tool which can exercise the scenario to produce the MOE, and camouflage performance data required as input for the analytical tool. The analytical tools can range from simple mathematical equations through complex computer simulations of a battle. Computer models with direct usefulness to camouflage are discussed in Section 6.2.2. References 5, 6, and 18 are examples of military worth analyses of camouflage.

6.1.4 Specification Testing

Camouflage specifications represent material properties and construction features which are required for the camouflage to perform as intended. The special features of camouflage specifications are that they describe and control the characteristics of a material surface which affects its appearance. Color and gloss are representative surface properties controlled by specifications. An example of a camouflage specification is MIL-C-52771A(ME) for Camouflage Screening Systems, Modular, Lightweight, Synthetic.

The desirable reflectance properties of military coating are not always adequately judged by visual comparison with a color standard. The reflectance properties of paints and fabrics are determined, instead, by spectrophotometers (Reference 19), capable of measurements in the ultraviolet, visual and infrared regions. Shine or gloss is similarly measured by a glossmeter as described in Reference 20 or by a goniophotometer. Research-type spectrogoniophotometers have been built which allow the viewing angle and illuminating angle to be varied.

The introduction of the recording spectrophotometer provided personnel engaged in testing camouflage a new and rapid means of obtaining relative reflectance (and transmittance) data. Mathematical formulations derived from other research permitted this data to be reduced to a color specification.* The spectrophotometer views only a very small sample area and performs a measurement under a set of special circumstances which exclude the specular reflection.** A spectrophotometer may record the same reflectance curve for a wool blanket and its silk border, even when they do not look alike.

Nature achieves appearance characteristics through many mechanisms other than the one defined as technical color. The selective ability of camouflage materials to scatter radiation and produce shadows on levels ranging from microscopic to macroscopic is important in producing contrast and form. The spectrophotometer is especially useful in specification testing wherein the color characteristics of the material have been fixed, and the task is to maintain a given tolerance in the color of that material. Test specifications for camouflage will vary depending upon the type of materials being used, the application and desired objective. Table 6-1 compiles a listing of more common test methods which may be helpful with the evaluation of camouflage materials.

* C.I.E. (Commission Internationale de l'Eclairage), International Commission on Illumination

** (Specular effects can be included)

Table 6-1

TYPES OF TESTS FOR CAMOUFLAGE

I. ENVIRONMENTAL

A. MIL-STD-810C, ENVIRONMENTAL TEST STANDARDS

Characteristic	Test Method
Low Pressure (Altitude)	500.1
High Temperature	501.1
Low Temperature	502.1
Temperature Shock	503.1
Temperature - Altitude	504.1
Solar Radiation (Sunshine)	505.1
Rain	506.1
Humidity	507.1
Fungus	508.1
Salt Fog	509.1
Dust (Fine Sand)	510.1
Explosive Atmosphere	511.1
Leakage (Immersion)	512.1
Acceleration	513.2
Vibration	514.2
Accoustical Noise	515.2
Shock	516.2
Temperature - Humidity - Altitude	518.1

B. Icing - 0.25 inch thick build up and $0^{o}F$ has been used

C. Snow - 20 lb/ft^2 has been used

D. Wind - Steady at 45 mph with gusts of 52 mph has been used

II. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) METHODS

Characteristic	Test Method
Accelerated Weathering	G-26
Water Absorption	D-471
Breaking Strength	D-1682

III. FEDERAL TEST METHOD STANDARD 141 - PAINT, VARNISH, LACQUER, AND RELATED MATERIALS

Characteristic	Test Method
Heat Resistance	6051
Flexibility	6221, 6222, 6223

Table 6-1 (CONTD)

TYPES OF TESTS FOR CAMOUFLAGE

Characteristic	Test Method
Paint Adhesion	6317, 6301.1, 6302.1, 6303.1
Accelerated Weathering	6151, 6152
Humidity Exposure	6201
Blocking	6216
Salt Fog Exposure	6061
Color of Pigmented Coatings	4250
Color and Apparent Reflectance	4251
Drying Time of Coatings	4061.1
Specular Gloss	6101, 6103, 6104
Fineness of Grind	4411.1
Spectral Reflectance	6241
Freeze-Thaw Resistance	3012
Immersion Resistance	6011
Abrasion Resistance	6191, 6192, 6193
Light Fastness of Pigments	4561.1

IV. FEDERAL TEST METHOD STANDARD 406 - PLASTICS, METHODS OF TESTING

Characteristic	Test Method
Tackiness	1131
Colorfastness to Light	6031
Abrasion	1091, 1092
Accelerated Weathering, etc.	6011, 6022, 6023, 6024
Brittleness Temperature	2051
Flame Resistance	2023
Gloss	3051
Light Diffusion	3031
Haze and Transmittance	3022
Mar Resistance	1093
Mildew Resistance	6091
Optical Uniformity and Distortion	3041
Diffuse Luminous Transmittance	3032
Chemical Resistance	7011
Salt Spray	6071
Shatterproofness	1073, 1075
Shockproofness	1072

Table 6-1 (CONTD)

TYPES OF TESTS FOR CAMOUFLAGE

V. FEDERAL TEST METHOD STANDARD 601 - RUBBER, SAMPLING AND TESTING

Characteristic	Test Method
Petroleum Immersion	6001
Abrasion	14111
Adhesion	8211
Accelerated Aging	7001
Water Immersion	12411, 6631
Liquid Immersion	6411, 6421
Hydrostatic Resistance	10511
Low Temperature Flexibility	5211, 5711, 5611
Resistance to Light	7311
Tensile Strength	4111
Tensile Stress	4131
Tackiness	13141, 13151
Tear Resistance	4211, 4221

VI. FEDERAL TEST METHOD STANDARD 191 - TEXTILE TEST METHODS

Characteristic	Test Method
Accelerated Fading	5660
Mildew Resistance	5750, 5760, 5762
Flame Resistance	5900, 5903, 5904
Burning Rate of Cloth	5906, 5908, 5910
Accelerated Aging	5850, 5851, 5852
Low Temperature Flexibility	5204
Cracking	5651
Tear Strength	5132, 5134, 5136
Hydrostatic Resistance	5512, 5514, 5516
Coating Adhesion	5970
Blocking	5872
Weathering Resistance	5800, 5804
Colorfastness to Light	5662
Breaking Strength	5100, 5120, 5122
Abrasion Resistance	5300, 5302, 5304, 5306, 5308
Water Resistance	5500, 5502, 5504, 5520, 5522, 5524, 5526, 5528

6.2 CAMOUFLAGE TEST AND EVALUATION METHODOLOGY

6.2.1 Perceptibility Tests

Perceptibility tests are characterized by a large number of variables which may have a strong influence on the outcome of the tests. The following considerations are offered to the equipment developer as a guide to the preparation of his perceptibility test to ensure that the most important test variables are accounted for or controlled.

The first consideration is to construct a realistic test situation based on the expected operational scenario. The terrain and season used in the test should represent this scenario. Visual camouflage designed for central Europe should be tested in a similar background and not, for example, in a U.S. desert test area. Arctic camouflage designed to defeat ultraviolet sensors should be tested in a snow-covered terrain.

The field of view of the remote sensing system should include more than just the test item. The future battlefield may be dense with target-like objects which tend to confuse enemy observation capabilities. When an operational scenario is of interest, distracting objects should be included. During the conduct of the test, the sequence of detection should be recorded such that the effect of the distracting object can be determined and separated from the effect of the camouflage treatment of the test item. If the test item invariably operates in proximity to other items or activities, the individual items of an air defense site for example, these should also be represented or simulated in the display.

In general, uncamouflaged equipment should not be displayed along with camouflaged equipment in tests except where such is likely to happen in real situations. The detection of one object has a great influence on the detection of other nearby objects through localization of the search area, focused attention, and reinforcement of effort by the observer.

The proficiency of the personnel setting up the test item at the test site can be expected to have a significant influence on the perceptibility of the camouflage. The performance of the camouflage in the hands of expert camoufleurs may be quite different from that performance in the hands of the using units. Camouflage test results should be considered as optimum performance which may not be achieved by the using unit without extensive training.

Consistent siting is of particular importance in the tests of the comparative performance of camouflage treatments. Variations in siting of the test items in the background are capable of masking variations in performance of the test items.

The remote sensor used in the test should closely match the performance of the validated threat sensor that the camouflage was designed to defeat. The validated threat sensor is often considered to exhibit state-of-the-art

performance but there may be situations where the performance of the threat sensor has been assessed at less than state-of-the-art. Success of a camouflage treatment against a superior sensor is a welcome situation, but failure is an uncertain answer to the performance against the validated threat sensor.

The second consideration is that of the statistical design of the perceptibility test and the analysis of the test results. Camouflage perceptibility tests are characterized by a small number of observations with a large scatter in the results. Costs limit the amount of data obtainable, and the large scatter is due to the dependence upon observer judgments (which are notorious for their variability). The sensitivity of camouflage performance to the local, not global, features of the weather, terrain and background also add to this diversity. Small sample statistics, for sample size less than 30, provides the tools to enable the most meaningful conclusions to be drawn from the least costly test.

Perceptibility tests are of two basic types: the determination of the performance of a camouflage treatment under a variation of a test stimulus such as range or search time, Figure 6-2 (an example of sensitivity testing); or the comparison of the performance of several candidate camouflage treatments (an example of variance analysis).

In sensitivity tests, a test object is subjected to a stimulus (range) and a quantal response (detection or not detection) is obtained depending on whether or not some critical physical threshold was exceeded for that particular test. A second characteristic of sensitivity tests is that they are destructive to the situation being tested no matter the outcome of the test. For example, an observer is allowed only one opportunity to observe a camouflaged item from a given position due to the learning curve associated with the search process. A second opportunity would not be a true replica of the initial opportunity. A third characteristic of sensitivity tests is that the percentage of responses (detections) normally increases with the stimulus (decrease in observation range). See References 21 and 22.

Analysis of variance techniques are used to determine significant differences in the sample means of the measure of camouflage performance due to different camouflage treatments or different environmental variables. If there are significant differences among the sample means, Duncan's Multiple Range Test may be used to determine which of the various differences among the sample means may be statistically significant. Duncan's Multiple Range Test is a post hoc comparison, after ranking, of each pair of sample means using a set of significant differences that depend upon, and increase with, the range between the ranked means. See References 23, 24, 25, and 26.

The third consideration is that of complete and thorough documentation of the test. The location and orientation of the test items and sensors should be mapped with respect to significant elements of the background, terrain and clutter objects. Descriptions of the condition of the test

item, such as surface temperature, target-background visual contrast, and equipment operating frequencies should be recorded. The operational status of the equipment (statements of the warm-up routine or operating power level) should also be recorded. The paths of the sensor and of the camouflaged item through the test area should also be mapped.

Meteorological data such as temperature, relative humidity, wind speed and direction, visible range, cloud cover, illumination level, weather state, or sun angle should be measured and recorded as required to meet the needs of a specific test. The parameters of the remote sensing system such as film and filter combination, lens focal length and field of view, target size and position in the field of view, sensor-target range, sensor direction (vertical, oblique, side-looking, ...), and sensor resolution at the target should also be recorded.

The fourth consideration is that of test conduct. The inevitable variations in test conditions such as time of day, season of year, sun angle, aspect of item exposed to the sensor, existence of line of sight, weather, atmospheric state, and meteorological visibility should be minimized factored into the statistical design of the test and recorded during the test.

The observer population should be calibrated with respect to psychophysical performance (visual acuity, color blindness, hidden figures test scores), false detection rates, motivation, training, experience, prebriefing, and lack of combat stress. Persons chosen as observers should be representative in capability, and should be given motivation and training to respond as would the population against which the camouflage is directed. This of course is an ideal seldom accomplished, but care should be taken to judge the trial results with these factors in mind.

Experience has shown that proper motivation is extremely important in this form of testing. Image interpreters given the task of finding tanks in a series of photographs often find tanks even if there are no tanks.

Reasonable cover stories should be used in observer briefing to incorporate as much combat realism as possible in their search task. The problem statement should be the same as that which would be given in a real military search problem such as "Report all items suspected to be military equipment," and not "Can you see a camouflaged object from here?"

The sensor search strategy should be specified. The test area could be subjected to free search, raster search pattern, or a pattern dictated by the path of the sensor platform. The maximum allowable search time should be specified.

It is most important to furnish an operational definition of the terms, such as detection or target acquisition, used in the instructions to the observer. For the purposes of some tests, for example, target acquisition may be said to have occurred if the observer names the target and aligns a weapon sight to within a specified angle of the line of sight to the target.

"Blind" tests should be considered where few clues are given to the test observers. For example, image interpreters may be instructed to report any military item found in a series of many images rather than be instructed to report camouflaged shelters in a particular image.

Calibration objects should be included in the field of view if possible. These could be resolution and grey scale test patterns, known thermal sources, radar reflectors of known cross section, etc., depending upon the sensor system involved.

The inclusion of grey scales within an observed scene has grown as a testing practice. Properly employed, these can provide data concerning the brightness relationships within an image. Problems arise when the scales are employed in different scenes at even slightly different positions relative to the sensor and light source. The grey scales should be oriented such that specular reflections are not recorded. This technique is a valuable tool in a laboratory where all control elements can be kept constant, but it is subject to great error when used in the field. Large sheets of celotex® (used for their semitextured surface) deployed as a grey scale and photographed from the air at even slight angles off vertical will produce different results in photographs taken from different compass directions. The variance becomes greater as the sun becomes brighter or is positioned lower in the sky. This same phenomena may be seen in aereal photographs of terrain containing black top roads. From one position the roads appear black; from another position they appear light or even white. This is an example of specular reflection dominating inherent color. The use of grey scales depends upon the purpose of the test. For tests other than brightness matching, the grey scales would be incompatible with camouflaged items in the same image.

Things are seen primarily because their form and size are contrasted against a background, resulting primarily from shadows on the object and the shadow cast by it on the surroundings. Smooth surfaces are more highly variable in specular reflection than are textured surfaces. Texturing a surface increases the scattering effect, and thus provides more consistency of reflection with viewing and illuminating angles. Grey scales for use in field tests should, therefore, either be multifaceted spheres to permit selection of that set of facets applicable to that observation situation or, if flat, they should be textured and placed in a consistent relationship to the sensor throughout any test series.

6.2.2 Combat Models

A combat model is a representation of real combat and produces numerical output which can be related to tactical actions. The prime characteristics of models are resolution, responsiveness, and realism (Reference 27).

Resolution is the detail to which the model plays the force. A greater degree of resolution implies more detailed examination of a system. A low resolution model may equate detection with the target being within some

critical range of the sensor; whereas a higher resolution model may determine detection based upon line of sight and target to background contrast. As the resolution increases, the model becomes more complex and the resources it requires become greater. High resolution models usually examine units of battalion size or lower. DYNTACS, BONDER/IUA, AMSWAG, MERDC BARRIER OBSTACLE EVALUATION MODEL, CAMWTH, SCREEN AIR, SCREEN GROUND, WAGMBO/VALUATE, BLDM, TACOS, COMANEX, and CARMONETTE are high resolution combat models.

Larger forces may be examined by models of lower resolution, since some consolidation of units and times can be accepted for forces such as divisions which have thousands of elements and operate over long periods. Division Battle Model (DBM), Division War Game (DIVLEV), ADVICE II, CONAF Evaluation Model (CEM), DIVTAG AND LEGION are low resolution models of division and larger forces.

The larger the force, the greater the problems of obtaining high resolution. One way around this problem is the integration of high and low resolution models. CARMONETTE and COMANEX have been integrated into DBM. In this integration, DBM identifies unit engagements which are then evaluated by the high resolution models. The battle assessments are then returned to the DBM model.

Model responsiveness is considered from two aspects: preparation time and execution time, and adequacy of information to respond to questions in the Military Worth Analysis. Although these two aspects conflict, a compromise may be worked out in which a combination of models is used; a model of higher resolution for in-depth information, and a more aggregated model to cover a wider span of variations is a typical compromise.

The realism of the model is improved if the integrated battlefield is played. Ideally, all systems should be examined in the complete military environment in which they will be employed. In an attempt to cope with the resource problem, models often play pure or incomplete battlefields. For example, when tanks are examined, the models may play tanks and antitank weapons while ignoring the influence of infantry on the battlefield.

Dynamism is an important element of reality. A dynamic model is one in which for each action of an element on one side, there is a logical reaction on the other. If Blue fires at Red, Red ducks. If Red defenders can observe an area, Blue attackers avoid it. Dynamic models for the computer originally posed so many technical questions that non-dynamic models were used. But advances in modeling techniques have allowed the development of dynamic models which operate on the basis of decision rules which are a part of the program. These decision rules are applicable to any element at any time in the battle.

The current state-of-the-art in combat models which directly relate to analyses of the military worth of camouflage have been assessed in References 5, 6, and 8.

6.2.3 Compatibility Testing

A determination of the compatibility of the camouflage treatment with the operation of the equipment should be made during a field test. Some equipment is static and is little hindered by camouflage treatments, but a well camouflaged rocket launcher that can neither fire nor maneuver is of little value. The weight, bulk, shipping, and storage requirements of the camouflage should be noted. The procedure, time, and personnel required to unpack, install, clean up the site, take down, and repack the camouflage should also be noted.

Particular attention should be paid to troop handling experiences with the camouflage. The camouflage treatment should result in minimal interference with the operation or performance of the item, and the camouflage should not be damaged during normal operation of the item. The compatibility test should note any of the following: mobility restrictions, restricted fields of fire; obscured sights and antenna beams; restricted antenna and weapon motion; lack of clearance from muzzle blast, rocket and engine exhaust; inability to withstand vibration, transportation stresses, and contact with underbrush; expected surface scuffing; susceptibility to chemical/biological agents and capability of decontamination; weather resistance (wind, rain, humidity, ultraviolet exposure, ...); obstructed cooling air intakes and exhaust flows; and restrictions of access by users of the equipment item.

6.3 REGISTER OF CAMOUFLAGE TEST FACILITIES

There are many specialized facilities available to the equipment developer for use in his testing of the camouflage treatment applied to his item/system. Table 6-2 is an index to the facilities which are described in the following register. These data were obtained from Reference 28 unless otherwise indicated.

Table 6-2

INDEX TO CAMOUFLAGE TEST FACILITIES

Facility Capability	Facility ID Number
Acoustic Camouflage	4
Fabric Testing	24
Image Intensifier Test	14, 17, 20, 22, 27
IR Sensor System Evaluation	21
IR Signatures	8, 9, 10, 11, 13, 15, 16, 29
Laser Countermeasure Evaluation	32
Laser Guided Weapons Homing Tests	13
LLLTV Test	14, 25, 31
Magnetic Signatures	25, 30
Photographic Image Evaluation	26
Radar Cross Section	34
Radar Homing System Evaluation	23
Radar Hot Spot	34
Seismic Signatures	25
Smoke, Aerosol Testing	1, 2, 3, 5, 7
Sonic Signatures	25
Spectral Reflectance	12, 31, 33
Test Range	28
Thermal Images Test	14, 18, 22, 27
Visual Simulators	35
Visual Terrain Model	6, 19, 22, 35
Rubber & Coating Facilities	36

TEST FACILITY:	FACILITY NO.
TOXIC DISSEMINATION CHAMBER	1

FACILITY LOCATION:	ORGANIZATION:
Edgewood Arsenal POINT OF CONTACT: Mr. Stroupe TELEPHONE: AV 584-2743 (301) 671-2743	Chemical Systems Laboratory Development Support Division DRDAR-CLJ-M

The facility is used for testing and assessing under static conditions agents simulants, munitions, protective equipment, and alarm systems. In addition, the chamber provides a capability for basic research in dissemination processes, study of decomposition of aerosols and vapors as a function of time; study of cloud properties such as particle size, vapor and aerosol concentrations; and agent simulant, decomposition as a function of time. The chamber is a cylindrical shape, 30' dia x 19' H, fabricated from 3/4" steel, air conditioned from +70°F to +85°F, has no humidity control, however, steam can be injected. Pressure can be reduced to 12 inches H_2O. Equipment is available for the complete mixing of the effluent; sampling of vapor, aerosols and particulates both in suspension and fall-out; complete decontamination and temperature and pressure measuring instrumentation.

TEST FACILITY: DISPERSION/DISSEMINATION SYSTEM DEVELOPMENT FACILITY	FACILITY NO. 2

FACILITY LOCATION: Edgewood Arsenal	ORGANIZATION: Chemical Systems Laboratory Munitions Division DRDAR-CLN
POINT OF CONTACT:	
TELEPHONE: AV 584-2225 (301) 671-2225	

The facility is used to develop Ammunition, Explosives and Pyrotechnics, Chemical Deterrents and Riot Control Munitions or Devices. Available is a Dispersion/Dissemination Test Area with twin 150-ft towers, which can be used for long path evaluation of the effectiveness of new SMOKE concepts against lectro Optical sensor systems; an Outdoor Subsonic (small arms) Ballistic Test Range, 300 meters, instrumented with outboard velocity screens. Within the support area is a Ballistic Parameter Measurement Device allowing for transverse and axial moment studies of various munitions. The Subsonic Ballistic Test Range is set out approximately 50 feet from a 46' x 20' quonset hut, on an azimuth of 124° for a distance of 300 meters with an impact mound of earth approximately 10 feet high and 50 feet wide. The gun mount is approximately 42 inches above level ground. The range surface is of large and crushed rock fill, over a swamp area, onto hard ground. The width is approximately 20 meters at gun mount, narrowing to approximately 10 meters at mid range, expanding to about 40 meters at 300 meters (mound). Available are two 150-ft steel towers with platforms. A quonset hut is available with installed instruments and equipment for ballistic measurements and nondestruct assessment of functioned munitions by X-ray, 15 to 100 Kwp @ 3 ma., using Polaroid film packs. Mechanical measurement equipment and a Ballistic Measurement Device are also available, in a controlled atmosphere, to provide for transverse and axial moment studies of various munitions. A Support Area provides for fabrication of prototype instrumentation.

TEST FACILITY:		FACILITY NO.
EXPLOSION TEST CHAMBER		3
FACILITY LOCATION: Edgewood Arsenal POINT OF CONTACT: Mr. Stroupe TELEPHONE: AV 584-2743 (301) 671-2743	ORGANIZATION: Chemical Systems Laboratory Development Support Division DRDAR-CLJ-M	

The Explosion Test Chamber performs testing of chemical warfare agents, munitions and such other items as protective equipment, alarm systems, and flame throwers, both portable and mechanized. The Chamber is also used for basic research in dissemination processes, study of decomposition of aerosols and vapor as a function of time, study of cloud properties such as particle size, vapor and aerosol concentrations, and agent decomposition as a function of time. The Chamber has a volume of 16,000 cu. ft. which may be automatically controlled and maintained at $-65^{o}F$ to $160^{o}F$ with a relative humidity from 20% to 95%. Facility capabilities include static firing of munition with up to 1 lb. of TNT, complete mixing of the effluent, sampling of vapors, aerosols and particulates; decontamination facilities, temperature and pressure measuring instrumentation. Access to the Chamber is through a 10' x 13' door.

TEST FACILITY: ACOUSTICS FACILITY		FACILITY NO. 4
FACILITY LOCATION: Picatinny Arsenal POINT OF CONTACT: Mr. Dan Ramer TELEPHONE: AV 880-6346 (201) 328-6346	ORGANIZATION: Technical Support Directorate	

This facility provides capability for the design, development and testing of analog and digital, acoustically oriented instrumentation. Limited capability exists for real-time data acquisition and reduction of acoustically generated data.

Dedicated equipment is of the general instrumentation type, suitable for the generation and measurement of amplitude and time varying signals compatible with the specialized instrumentation undergoing development testing.

The facility is used for determining acoustic signature of fuzes and helicopters. Facility is also used to determine aeronautical balance of airborne equipment.

TEST FACILITY:	FACILITY NO.
INDOOR FLARE TEST FACILITY	5

FACILITY LOCATION:	ORGANIZATION:
Picatinny Arsenal POINT OF CONTACT: Mr. Jesse Tyroler TELEPHONE: AV 880-2291 (201) 328-2291	Large Caliber Weapons System Laboratory DRDAR-LCE

This flare tunnel is used for the comparison of pyrotechnic compositions and complete items under controlled conditions. The facility consists of a hearth or burning chamber, a chimney stack and fan for smoke removal, and a long chamber for the placement of photometric instrumentation. This tunnel is considered to be a testing standard and its configuration must be duplicated by Army contractors or flare items. Photo cells, corrected to human eye response, strip chart recorders, integrators, radiometers, and chromacorders provide test results of candle power, color ratio, spectral distribution, and chromaticity. Flares up to two million candle power can be tested in this facility.

TEST FACILITY:	FACILITY NO.
PYROTECHNIC TERRAIN MODEL	6

FACILITY LOCATION:	ORGANIZATION:
Picatinny Arsenal	Large Caliber Weapons Systems Laboratory
POINT OF CONTACT: Mr. Jesse Tyroler	DRDAR-LCE
TELEPHONE: AV 880-2291 (201) 328-2291	

The Pyrotechnic Terrain Model is 40 ft. long and 10 ft. wide. Contained within the model are various terrain features typical of southeast Asia - on a 160/1 scale. It is housed in a building that can be completely darkened for viewing by observers under controlled illumination. Target motion is provided and an overhead platform (fixed) is available for aircraft observation. A console of instrumentation simulates actual flares in dynamic application. Tungsten filament lamps are used to illuminate the terrain. These light sources simulate actual flare parameters such as spectral color, flicker, descent rate, and intensity.

The terrain model permits parameters to be varied under controlled conditions and to allow the actual effect of each of these parameters on visual recognition to be determined. The model is also very useful in establishing pyrotechnic illumination requirements. Instrumentation includes an FM magnetic tape recorder and a 36 channel recording oscillograph.

TEST FACILITY:	FACILITY NO.
PYROTECHNICS LABORATORY AND TEST FACILITY	7

FACILITY LOCATION:	ORGANIZATION:
Picatinny Arsenal POINT OF CONTACT: Mr. Jesse Tyroler TELEPHONE: AV 880-2291 (201) 328-2291	Large Caliber Weapons System Laboratory DRDAR-LCE

Laboratory and Test Facilities consist of an array of equipment capable of testing every conceivable output of pyrotechnique systems. These systems consist of flares, decoys, signals (radiation and/or smokes, markers, tracers, decoys, whistles, etc.). This facility includes equipment and instrumentation to quantitatively measure total radiation outputs, radiation efficiencies, burning rates, time delays, color purities, effects of humidity and long term temperature storage, and the size and shape of solid particles in the micron and sub-micron regions.

TEST FACILITY:	FACILITY NO.
FOURIER TRANSFORM SPECTROMETER, DIGILAB (FTS-14)	8

FACILITY LOCATION:	ORGANIZATION:
Picatinny Arsenal POINT OF CONTACT: Mr. Jesse Tyroler TELEPHONE: AV 880-2291 (201) 328-2291	Large Caliber Weapons System Laboratory DRDAR-LCE

The instrument is capable of generating infrared spectra in fast time in both emission and absorption. Its utility includes (1) the acquisition of IR spectra of flares, signals, and other pyrotechnic items and, (2) the identification of atmospheric pollutants. The instrument is based on a Michaelson interferometer and is capable of 0.5 cm^{-1} resolution. These are interchangeable beam splitters: Fe_2O_3 on quartz for the range 10,000 - 3300 cm^{-1}, GE on KBr for 3800-400 cm^{-1} and three mylar films spanning the range 400-20 cm^{-1}. The optical system is evacuable for far infrared studies. A triaglycine sulfate detector is used below 4000 cm^{-1} and a PbSe detector from 4000-7700 cm^{-1}. The available frequency range is thus 20-7700 cm^{-1} (500-1.3μm). Control functions are provided by a Data General Nova 1200 Mini Computer which also performs fast Fourier Transforms. Emission spectra can be plotted directly on a Houston DP-1 digital plotter while absorption spectra are ratioed against a reference spectrum and can be plotted in linear transmittance linear or logarithmic absorbance. The digital spectra information can be listed by the teletype or punched onto paper tape.

TEST FACILITY:	FACILITY NO.
DYNAMIC IRCM SIMULATOR	9

FACILITY LOCATION:	ORGANIZATION:
White Sands Missile Range POINT OF CONTACT: Mr. Tom Atherton TELEPHONE. AV 258-2025 (915) 678-2025	Office of Missile Electronic Warfare Electronic Warfare Laboratory DRSEL-WLM-AD

This facility is used to evaluate the effects of various infrared countermeasures on heat-seeking missiles and other infrared equipment. A Missile Flight Simulator is used with a computer to simulate real-time, closed-loop, dynamic missile flights in both benign and IRCM environments. Optical equipment with diameters up to 5.5 inches can be evaluated over the 1.7- to 5.5- micrometer band. The facility can simulate up to 5 different infrared sources. Instrumentation is available for spectrally calibrating the irradiance and for measuring, displaying, and recording flight trajectories, miss-distance, infrared equipment response, etc. Infrared signatures of targets and countermeasures are modelled. The simulator is operated in a laboratory 80' L x 20' W x 11' H.

TEST FACILITY:	FACILITY NO.
INFRARED MEASUREMENTS AND DATA REDUCTION FACILITY	10

FACILITY LOCATION:	ORGANIZATION:
White Sands Missile Range POINT OF CONTACT: Mr. Leonard Holden TELEPHONE: AV 258-1809 (915) 678-1809	Office of Missile Electronic Warfare Electronic Warfare Laboratory DRSEL-WLM-MM

The instrumentation utilized includes a variety of spectrometers and radiometers in conjunction with digited recording and formating equipment. Inputs, in addition to received infrared information, include target tracking and position data, meteorological data, and sequence of events timing. These inputs are provided by a precision tracking mount, a range-only radar, a target mounted attitude system and suitable meteorological and time code generation equipment. Target consists of all army aircraft and missiles and those foreign systems which pose a threat to the army; electronic countermeasures developed for army weapon system and countermeasure design and development.

TEST FACILITY:	FACILITY NO.
SPECTRAL IMAGING SYSTEM	11

FACILITY LOCATION:	ORGANIZATION:
White Sands Missile Range POINT OF CONTACT: Mr. Leonard Holden TELEPHONE: AV 258-1809 (915) 678-1809	Office of Missile Electronic Warfare Electronic Warfare Laboratory DRSEL-WLM-MM

Infrared spectral imaging system providing spatial imaging data in the 1.5 to 5.5 micrometer region of the spectrum. Twenty seconds per scan; approximately 20,000 resolution items per scan. The instrument operates on Fourier Transform principle which provides higher signal-to-noise ratios and faster scanning times than normally available with dispersion instruments.

TEST FACILITY:	FACILITY NO.
SPECTRAL MEASUREMENT SYSTEM	12

FACILITY LOCATION:	ORGANIZATION:
White Sands Missile Range POINT OF CONTACT: Mr. Leonard Holden TELEPHONE AV 258-1809 (915) 678-1809	Office of Missile Electronic Warfare Electronic Warfare Laboratory DRSEL-WLM-MM

Infrared measurement system consisting of three interferometer spectrometers, digital data acquisition, recording and reduction system and a van in which equipment is operated. Provides absolute spectral data in the 1.5 to 14 micrometer region. In addition, the diffuse measuring capability provided by the sphere is unique in the field of far infrared spectral reflectance measurement.

TEST FACILITY:	FACILITY NO.
TERMINAL HOMING LABORATORY	13

FACILITY LOCATION:	ORGANIZATION:
White Sands Missile Range POINT OF CONTACT: Mr. Robert J. Clauson TELEPHONE: AV 258-2736 (915) 678-2736	Office of Missile Electronic Warfare Electronic Warfare Laboratory DRSEL-WLM-ST

The terminal homing laboratory utilizes electrical and electro-optical test equipment to perform ECM and ECCM testing of electro-optical terminal homing laser guided weapons system. Data recording capabilities include strip recorders, scope cameras, magnetic tape, video tape, and voice recorders. Electronic test equipment includes wideband oscilloscopes, precision delay generator, programmable synthesizer, computing counting system, as well as the standard laboratory test equipment. Electro-optical test equipment includes visible and near IR lasers, diode sources, and detectors, as well as radiometers, photometers, spectrophotometers, spectroradiometers and standard electro-optical test equipment.

TEST FACILITY:	FACILITY NO.
ADVANCED IMAGE EVALUATION FACILITY	14

FACILITY LOCATION:	ORGANIZATION:
Night Vision Laboratory (Ft. Belvoir) POINT OF CONTACT: Mr. James Wood TELEPHONE: AV 354-4074 (703) 664-4074	Visionics Technical Area DRSEL-NV-VI

The Advanced Image Evaluation Facility is a laboratory facility designed to measure key system performance parameters of photon imaging systems including low light level television systems, real-time-thermal imaging systems and image intensifier systems. The facility is highly automatic with all major testing conditions under computer control. Data output is provided by a hard copy unit interfaced to a key board CRT. The key system performance parameters measured are OTF, Limiting Resolution, Display Cosmetics (noise, uniformity) and Signal Transfer Function.

TEST FACILITY:	FACILITY NO.
CALIBRATED THERMAL IMAGING SYSTEM, NEAR FIELD	15

FACILITY LOCATION:	ORGANIZATION:
Night Vision Laboratory (Ft. Belvoir)	Target Signatures Team
POINT OF CONTACT: Mr. Fred Zegel	DRSEL-NV-VI
TELEPHONE: AV 354-3625 (703) 664-3625	

This is a calibrated thermal imaging system which tests the amount of heat radiated by all varieties of tactical vehicles and objects in a broad range of geographic backgrounds. This is a highly complex electro-optical test instrument that is housed in its own mobile test laboratory with all the necessary support equipment. This equipment was developed by Texas Instruments, Inc. Imaging system specifications: 1.0 mrad instantaneous FOV, 525x525 picture elements and InSb and HgCdTe detectors, 30x30 degree FOV with 4.5 sec. scan time; temperature sensitivity to 0.1 degrees; temperature range from -14°C to +60°C. Higher temperatures obtainable with filters. All types of imaging tests and general signature tests are supported. Calibrated blackbody temperature wedge is printed alongside of the image. Needs 115V power; electronics must be kept warm. (Camera can be out in the weather but cannot get wet.) Relatively portable (camera unit weighs 60 lbs.); electronics weight 100 lbs.; does come equiped in a special van. Needs photo processing for development of film.

TEST FACILITY:		FACILITY NO.
FAR FIELD THERMOGRAPHIC SYSTEM		16
FACILITY LOCATION: Night Vision Laboratory (Ft. Belvoir) POINT OF CONTACT: Mr. Fred Zegel TELEPHONE: AV 354-3625 (703) 664-3625	ORGANIZATION: Target Signatures Team DRSEL-NV-VI	

This is a calibrated thermal imaging system which tests the amount of heat radiated by all varieties of tactical vehicles and objects in a broad range of geographic backgrounds. This is a highly complex electro-optical test instrument that is housed in its own mobile test laboratory with all the necessary support equipment. This equipment was developed by Texas Instruments, Inc. Imaging system specifications: 0.17 mrad instantaneous FOV, 525x525 picture elements and InSb and HgCdTe detectors, spectrally filtered with selectable narrow band filters; 30x30 degree FOV with 4.5 sec. scan time; 5x5 and 2.5x2.5 FOV with 20 sec. scan time; temp. sensitivity to 0.1 degrees; temp. range from -20°C to +1000°C. All types of imaging tests and general signature tests are supported. Calibrated blackbody temperature wedge is printed alongside of the image. Needs 115V power; electronics must be kept warm. (Camera can be out in the weather but cannot get wet.) Not at all portable except in special van. Needs photo processing for development of film.

TEST FACILITY:	FACILITY NO.
ELECTRO-OPTICS SIMULATOR	17

FACILITY LOCATION:	ORGANIZATION:
Night Vision Laboratory (Ft. Belvoir)	Visionics Technical Area
POINT OF CONTACT: Mr. Carl Stich	DRSEL-NV-VI
TELEPHONE: AV 354-6650 (703) 664-6650	

The Electro-Optics Simulator provides capability for man-machine evaluation of night vision intensifier systems. The facility consists of a 35 foot by 140 foot screen, observer rooms, unique projection systems which can simulate the nighttime tactical visual environment in a controlled and repeatable manner. The imagery used is still imagery of tactical target background situation, and is displayed in the wide screen format to provide a search angle of 80^{o}. The inherent contrast of the imagery is degraded by overlaying white light to synthesize atmospheric degradation. The brightness is adjustable over the range of 10^{-2} to 10^{-6} foot lamberts simulating moonlight to overcast starlite conditions. Test subjects occupy up to 6 observer stations which are furnished with observer response and data acquisition equipment. Representative of tests conducted are:

a. Detection in recognition thresholds versus light level contrast range in target type.
b. Search effectiveness versus magnification and field of view.
c. Search effectiveness versus look time.
d. Psychophysiological factors influencing observer response.

TEST FACILITY:	FACILITY NO.
INFRARED SIMULATOR	18

FACILITY LOCATION:	ORGANIZATION:
Night Vision Laboratory (Ft. Belvoir) POINT OF CONTACT: Mr. Carl Stich TELEPHONE: AV 354-6650 (703) 664-6650	Visionics Technical Area DRSEL-NV-VI

The Infrared Simulator synthesizes 2 dimensional thermal imagery of significant military targets in the spectral region of 3 - 15 microns. The imagery can be controlled to precise Delta T. The simulator is used to generate baseline data on man-machine performance of ground and airborne thermal imaging systems.

TEST FACILITY:	FACILITY NO.
3-D TERRAIN SIMULATOR	19

FACILITY LOCATION:	ORGANIZATION:
Night Vision Laboratory (Ft. Belvoir) POINT OF CONTACT: Mr. Fred Zegel TELEPHONE: AV 354-3625 (703) 664-3625	Target Signatures Team DRSEL-NV-VI

The 3-D Terrain Model is made up of 60 sections with a total real area of 2400 square feet. The model measures 40 feet wide by 60 feet long and is constructed on a one-foot urethane foam substrate. The topographical features represent typical middle European features and include a small section of desert. The natural features, i.e., foliage, soil, rocks, etc., faithfully reproduces the spectral reflection of their real world countries over the spectral region of 0.4 microns to 1.5 microns. Cultural features are presented in a stylized manner, and are finished with typical materials. The scale of the model is 400:1, giving a useful simulated area approximately 3 by 4.5 miles. Facility is equipped with a manually positioned 3-axia gantry with a 2 degree of freedom gimball for positioning a simulated flight platform in surveillance system.

TEST FACILITY:	FACILITY NO.
IMAGE INTENSIFIER	20

FACILITY LOCATION:	ORGANIZATION:
Night Vision Laboratory (Ft. Belvoir)	Image Intensification Technical Area
POINT OF CONTACT: Mr. Herb Pollehn	DRSEL-NV-II
TELEPHONE: AV 354-5310 (703) 664-5310	

This instrument generates the modulation transfer function curve for image intensifier tubes and their associated components over a wide range of input light levels. To overcome the inaccuracies at low light levels the system utilizes a digital synchronous signal reinforcement technique to improve the accuracy of the measurement. The input light target to the intensifier under test is a slit whose width and length are adjustable. The working distance between input and output objectives is variable. It is required that the input photocathode and output screen of the intensifier under test be parallel and on axis with each other. Off axis measurements up to 5mm are possible for non-inverting tubes, and 10mm possible for inverting tubes. Periodic photometric calibration of the input light source is essential for proper data generation. Light source color temperature is calibrated to 2870°C. The light level at the target with no filters is 5.9 $\times 10^{-2}$ F.C. Six N.D. 1 filters are available for lower light levels. The analyzer system samples 16 discrete spartial frequencies between 0.17 lp/mm and 50 lp/mm. Modes of operation include direct and digital synchronous signal reinforcement. Outputs are available on an oscilloscope, DVM, and print-out onto an X-Y recorder.

TEST FACILITY:	FACILITY NO.
ADVANCED SIMULATION CENTER INFRARED SIMULATION SYSTEM (IRSS)	21

FACILITY LOCATION:	ORGANIZATION:
Redstone Arsenal POINT OF CONTACT: Dr. John Johnson TELEPHONE: AV 746-2755 (205) 876-2755	Aeroballistic Directorate DRDMI-TDS

This simulation system is used in the design, development and evaluation of infrared (IR) sensor systems applicable to surface-to-air, air-to-air, and air-to-surface missiles. Sensors in the 0.2 to 0.4 and 1.0 to 5.0 micron bands are hybrid computer controlled in six degrees-of-freedom during the target engagement sequence. A gimballed flight table provides pitch, yaw and roll movements to the sensor airframe. A target generator simulates a variety of target/background combinations which includes tailpipes, plumes, flares, and fuselages in single or multiple displays against clear, clouded, overcast, or sunlit sky. These are then displayed in azimuth, elevation, range, and aspect by the target projection subsystem through a folded optical network, a display arm, and a display mirror. Simulation capability ranges from open loop component evaluation to closed loop total system simulation.

TEST FACILITY:	FACILITY NO.
ADVANCED SIMULATION CENTER ELECTRO-OPTICAL SIMULATION SYSTEM (EOSS)	22

FACILITY LOCATION:	ORGANIZATION:
Redstone Arsenal	Aeroballistics Directorate
POINT OF CONTACT: Mr. Bill Phillips	DRDMI-TDS
TELEPHONE: AV 746-3917 (205) 876-3917	

This facility provides realistic and precisely controlled environments for the non-destructive simulation of a wide variety of ultraviolet, visible and near infrared sensor systems. Actual sensors are hybrid computer controlled in six degrees-of-freedom while viewing targets under controlled illumination levels (10^{-4} to 10^{3} footcandles) in an indoor simulation chamber, and under ambient conditions on an outdoor simulation range. Three-dimensional (3-D) target simulation is provided on a 32 ft x 32 ft terrain/target model/transporter which features a variety of topographical and man-made complexes at 600:1 and 300:1 scales, removable model sections, and fixed and moving targets at any desirable scale. A moving projection subsystem provides two-dimensional (2-D) representation. A gimballed flight table, capable of simulating pitch, yaw and roll movements to the sensor airframe, is attached to a transport which moves both vertically and laterally. The terrain/target model is moved toward the flight table to provide the sixth degree-of-freedom. An adjacent high resolution TV/joystick console and helicopter crew station provide a means of evaluating man-in-the-loop guidance and target acquisition concepts.

<table>
<tr><td colspan="2">TEST FACILITY:
ADVANCED SIMULATION CENTER - RADIO FREQUENCY SIMULATION SYSTEM (RFSS)</td><td>FACILITY NO.
23</td></tr>
<tr><td>FACILITY LOCATION:
Redstone Arsenal
POINT OF CONTACT:
Mr. Maurice Belrose
TELEPHONE:
AV 746-2592
(205) 876-2592</td><td colspan="2">ORGANIZATION:
Aeroballistic Directorate

DRDMI-TDR</td></tr>
</table>

This facility simulates a missile's total mission from launch to intercept. Its primary application is in evaluation of RF active, semiactive, passive, and command terminal guidance systems for surface-to-surface, surface-to-air, air-to-air, and air-to-surface missiles. Guidance sensors and flight control systems perform in an environment where aerodynamic moments, angular motions, and electromagnetic signals are realistically produced. This system is primarily used for semi-active homing missiles. It operates on frequency ranges of 2 - 18 GHz. The maximum number of simultaneous targets is 4. The system consists of two 3-axis Rotational Flight Simulators (TARFS). The system also contains a Control System Aerodynamic Loader (CSAL). This is a precision hydromechanical device that simulates aerodynamic hinge moments on missile fin actuators. The CSAL is used to follow any fin motion applying positive or negative dynamic torques as programmed. The RF generation equipment consists of 4 target generators, a reference generator, 2 denial ECM sources and, fuze selection and attenuation.

TEST FACILITY:	FACILITY NO.
TEXTILES AND SOFTGOODS LABORATORY	24

FACILITY LOCATION: Aberdeen Proving Ground/ Material Testing Directorate POINT OF CONTACT: Mr. Dave Phillips TELEPHONE: AV 283-3714 (301) 278-3714	ORGANIZATION: Engineering Measurements and Analysis Division STEAP-MT-G

The facility is equipped for measurement of physical and mechanical properties of plastics, paper, rubber, leather and textile products. Tests performed are tensile strength, compressive strength, flexural strength, modulus of elasticity, tear strength, burst strength, flammability, cloudiness of glass, color, vapor transmission, air permeability, resistance to abrasion, and surface and volume electrical resistivity. The facility has available tension and compression testing machines with constant strain, constant load or constant displacement rate capabilities; water vapor transmission rate tester; air permeability tester; flammability testers; burst testers; abrasion testers; environmental chambers; color measuring systems; gloss meters; a haze meter; surface roughness meters; a surface and volume electrical conductivity system; stiffness testers; analytical balances; and other apparatus necessary to perform ASTM and FTMS testing. Chambers are available for salt spray tests, accelerated weathering, accelerated aging, fungus testing, sand and dust exposure, high altitude (low pressure) exposure, and testing at high and low extremes of temperature and humidity.

TEST FACILITY:	FACILITY NO.
REMOTE SENSOR TEST FACILITY	25

FACILITY LOCATION:	ORGANIZATION:
Electronic Proving Ground (Ft. Huachuca)	Materiel Testing Division
POINT OF CONTACT: Mr. Daniel Bruno	STEEP-MT-SS
TELEPHONE: AV 879-3303 (602) 538-3303	

This analog data acquisition and recording system covers a variety of transducers, signal conditioning instruments and recording equipment which are used to monitor a wide range of target and background signal characteristics. Transducers include 3 axis and single axis geophones, flux-gate, variable-mu and proton precession magnetometers and a range of acoustic sensors. Signal conditioners include 16 Ithaco Model 454 Portable Instrumentation amplifiers and 8 Model 4114 variable bandpass filters, and 12 Ortec Model 4660 differential bandpass amplifiers. Recording equipment includes a Honeywell Model 5600C 14 channel portable (DC operated) FM Magnetic tape recorder and a portable (DC operated) 12 channel oscillograph.

TEST FACILITY:	FACILITY NO.
IMAGE INTERPRETATION FACILITY	26

FACILITY LOCATION:	ORGANIZATION:
Electronic Proving Ground (Ft. Huachuca) POINT OF CONTACT: Mr. Hudgins TELEPHONE: AV 879-6157 (602) 538-6157	Materiel Testing Division STEEP-MT-SI

This facility is equipped with light-tables which support five image interpreters. The work area provides for large mosaic construction and ample film storage. The light tables are able to handle film with formats up to 9". The 371 Digital Comparison Viewer is an automated photographic interpretation and measuring instrument. Automatic measurements of X-Y coordinates are displayed in 10 micron increments. The optical system consists of 2 fiber optic image transmitting bundles, permitting comparison of front and rear spool imagery taken by different sensors at different altitudes. The eyepiece assembly provides a variety of viewing modes, including stereo, pseudo-stereo, binocular-monoscopic, 180° upright reversion and superimposed viewing. Variable objective and zoom magnification permit a large variety of scale matching and comparison possibilities over a 30:1 range. Aerial film formats from 70mm to 9.5" can be accommodated.

TEST FACILITY:	FACILITY NO.
INFRARED-OPTICAL TEST FACILITY	27

FACILITY LOCATION:	ORGANIZATION:
Electronic Proving Ground (Ft. Huachuca)	Materiel Testing Division
POINT OF CONTACT: Mr. Steward	STEEP-MT-SI
TELEPHONE: AV 879-6157 (602) 538-6157	

This facility is used to test the following: ground and airborne photographic, infrared, laser, and television sensors, audio visual, drone systems, and fiber optics. The facility includes a clean room which is an enclosed structure internal to the building and is temperature and humidity controlled. Clean room contamination is monitored and kept to less than 100,000 particles per cubic foot of air (0.5 micron size). Capabilities include precise measurements of optical component characteristics such as resolution, focal length distortion, astigmatism, curvature of field, and aberrations. Other measurements include interferometer measurements, optical film densities and dynamic (frequency dependent) performance characteristics of lenses. Laboratory equipment contained in the clean room is: optical bench, infrared spectrophotometer, interferometer, microdensitometer, camera calibrator, modulation transfer function test system, and vibration damped optical test bed.

TEST FACILITY:	FACILITY NO.
GAMBOA TEST AREA	28

FACILITY LOCATION:	ORGANIZATION:
Tropic Test Center, Canal Zone	Service Logistics Division
POINT OF CONTACT: Mr. John Buese	STETC-LD-S
TELEPHONE: AV 313/285-4410 CZ 85-4410	

Gamboa test area is approximately 16,000 acres bordering easterly-side of the canal near the midpoint of the Isthmus. The area has mostly broadleaf evergreen trees, but some semideciduous trees and a limited amount of marshland and grass areas are also present. This facility provides isolation during tests. The area can be used for communications and surveillance testing, munitions testing, vehicle testing, armament tests, construction of caves and tunnels, battlefield illumination tests, jungle vision studies, acoustics studies, atmospheric sampling studies, and soil studies. There are two permanently marked parallel courses, both 4 km long and a 2 km course for making portability evaluations of heavy loads. Telemetry is being used for performance measures of subjects involved in test projects. Eyesafe laser rifles are used to simulate rifle fire accuracy before and after load-carrying by troops. The area consists of naturally dissected hills, the highest elevation being about 180 meters. There are many steep slopes, some in excess of 60%. Ridges are sinuous, with narrow tops and long steep sides. Streams are closely spaced with a fine network of seasonal rills draining into numerous low gradient perennial streams.

TEST FACILITY:	FACILITY NO.
GUIDANCE AND CONTROL FACILITY	29

FACILITY LOCATION:	ORGANIZATION:
White Sands Missile Range	Army Missile Test & Evaluation Directorate
POINT OF CONTACT: Mr. Gil Adams	STEWS-TE-AG
TELEPHONE: AV 258-2033 (915) 678-2712	

This facility is used to perform rate table, optical and mechanical alignment, fuze, infrared and R-F countermeasure tests and target infrared energy measurements on missile guidance systems; detection systems, launch (and aiming) systems; and target acquisition systems. In the Missile launch area, both missile and target IR signatures are measured and correlated with Radar Flight Instrumentation, Range timing, and camera data. In the laboratory area, Rate Tables and Climatic, Countermeasure, R-F Infrared Laser environments are used and/or applied to test missile guidance packages.

TEST FACILITY:	FACILITY NO.
HDL MAGNETIC SIGNATURE FACILITY	30

FACILITY LOCATION:	ORGANIZATION:
Harry Diamond Laboratories	Optical and Magnetic Branch
POINT OF CONTACT: Dr. Giglio	DRXDO-RAC
TELEPHONE: AV 290-3170 (202) 394-3170	

The HDL Magnetic Signature Facility consists of two independent systems, the Magnetic Latitude Simulator (which can modify the ambient geomagnetic field at APG, simulating the geomagnetic field of any point on Earth or producing a zero field environment) and the Automated Magnetic Data Acquisition System (that measures, digitizes, and records 21 simultaneous close-in, under-the-vehicle magnetic signatures). (Note: This facility is located at Aberdeen Proving Ground, MD)

TEST FACILITY:	FACILITY NO.
FAR INFRARED SPECTROPHOTOMETER	31

FACILITY LOCATION: Mobility Equipment Research and Development Command (Ft.Belvoir) POINT OF CONTACT: Mr. Dallas Barr TELEPHONE: AV 354-2654 (703) 664-5739	ORGANIZATION: Research, Technology, Material Development, and Camouflage Standards Division DRDME-RT

This device is capable of measuring the total diffuse reflectance or transmittance of samples over the spectral region of 2.0-15.0 microns. The instrument operates on the Fourier Transform principle which provides higher signal-to-noise ratios and faster scanning times than normally available with dispersion instruments. In addition, the diffuse measuring capability provided by the sphere is unique in the field of far infrared spectral reflectance measurements.

TEST FACILITY:	FACILITY NO.
LASER, GLASS PULSED LASER, KORAD K1300; CO_2 CW LASER, COHERENT 41; TEA LASER	32

FACILITY LOCATION: Mobility Equipment Research and Development Command (Ft. Belvoir) POINT OF CONTACT: Dr. J. Fox TELEPHONE: AV 354-2654 (703) 664-5739	ORGANIZATION: Research, Technology, Material Development, and Camouflage Standards Division DRDME-RT

Glass Pulsed Laser, made by Union Carbide, capable of producing 0.5 joule at 1.06 micron in 20 psec, 10 joule in 20 nsec and 100 joule in 015 msec. Can be mode locked. Q-switched or conventionally pulsed at one pulse/45 sec. Can be double pulsed in Q-switched mode giving 4 joules/pulse with time separations continuously variable from 20 nsec. to 500 microseconds in increments as small as 10 nsec. CO_2 Laser capable of 340 watts continuous operation at 10.6 micron or pulsed operation with durations variable from 1 msec to 10 sec at repetition rates as great as 10^3 sec-1. TEA pulsed CO_2 Laser capable of 0.5 joule (10,6 micron) at durations variable from 0.2 to 2 microseconds. The repetition rate is continuously variable from 2 to .2 pulses per second. Energy and power monitoring devices are provided for the above.

TEST FACILITY:	FACILITY NO.
SPECTROPHOTOMETER, COMPUTERIZED SYSTEM	33

FACILITY LOCATION:	ORGANIZATION:
Mobility Equipment Research and Development Command (Ft. Belvoir) POINT OF CONTACT: Mr. Dallas Barr TELEPHONE: AV 354-2654 (703) 664-5739	Research, Technology Material Development, and Camouflage Standards Division DRDME-RT

This system is multi-purpose in that it may be adapted to the following measurements:

1. Special Emissivity. In the laboratory the system can be used to measure the emissivity of transparent and opaque samples in the 3.0 to 14.0 micron spectral region.
2. Spectral Radiance. In the field the system can remotely measure the radiance of targets. The data can be later evaluated by calculating target/background spectral contrast.
3. Spectral Transmissivity & Specular Reflectivity. The system can also be used for transmission and reflection measurements in the 2.5-20.0 micron spectral region.

TEST FACILITY:	FACILITY NO.
100 GHz RADAR CROSS SECTION MEASUREMENT AND DIAGNOSTIC IMAGING EQUIPMENT	34

FACILITY LOCATION:	ORGANIZATION:
Mobility Equipment Research and Development Command (Ft. Belvoir) POINT OF CONTACT: Mr. David Gee TELEPHONE: AV 354-2654 (703) 664-5739	Research, Technology, Material Development, and Camouflage Standards Division DRDME-RT

This equipment provides the capability to measure and evaluate the radar cross section and equipment signature from scale models. For example, measurements on a 1/10 scale model correspond to X-band (10GHz) cross section and imaging data. In the monostatic mode, the total reflectivity of a target may be measured at all azimuth (360^{o}) settings and most grazing angles. In the diagnostic imaging mode, individual scatterers are isolated and measured with a target resolution of 1/2 inch. Graphical, audio, and video displays are provided.

TEST FACILITY:	FACILITY NO.
VISUAL SIMULATION FACILITIES	35

FACILITY LOCATION:	ORGANIZATION:
Various	
POINT OF CONTACT:	
TELEPHONE:	

A variety of visual simulation systems that were designed for other purposes may be useful in evaluating visual camouflage. Existing flight simulators, for pilot training or aircraft engineering, and simulation systems designed to improve the performance of missile and fire control seekers are described in Battelle Report CAMTEC-TR-6 to USAMERADCOM, Dec. 1973, "Study of Feasibility of Visual Simulation for Camouflage Evaluation," with companion study by Singer Co. Simulation Products Division, Nov 1973, "Simulation of Camouflage."

TEST FACILITY:	FACILITY NO.
RUBBER AND COATED FABRICS FACILITIES	36

FACILITY LOCATION:	ORGANIZATION:
Ft. Belvoir, Va.	Materials Technology Laboratory
POINT OF CONTACT:	DROME-VO
Mr. Fred Cafterman	
TELEPHONE:	
AV 354-5889 (703) 664-5889	

6.4 SAMPLE TEST PLAN

In addition to the selection of what to test for and how to create a realistic test situation which will produce valid test results, a description will be needed of how to conduct the test. A test plan, detailing how to conduct the test, needs to be written for those experiments, tests, and evaluations for which there are no established procedures or specifications. The test plan defines the test in all necessary detail by stating the objective of the test, all logistical requirements, the test procedure, and the data analysis method to be used.

The following outline has been abstracted from recent MERADCOM camouflage tests plans (Reference 19) and includes all the elements necessary for a field test of the perceptibility of the camouflage of individual items of equipment:

- Statement of the objective of the test.
  (to evaluate..., to determine...)

- Statement of the hypothesis that the statistical analysis is to answer.
  (the null hypothesis that there is no difference in the detection range of several candidate camouflage treatments, etc.)

- Identification of the variables involved in the test.
  Dependent (search time, detection range, etc.)
  Independent (camouflage treatments, sensor systems, etc.)

- List of test support to be supplied by the equipment developer.
  Test director and assistant to be responsible for and and approve technical aspects of the test conduct.
  Technical assistants to be responsible for the proper care and operation of the test items.
  The items to be tested and associated support equipment and maintenance materials.

- Specification of test support to be supplied by the tester.
  Test coordinator and alternate.
  Data recorders, equipment operators, drivers.
  Test subjects - number required, length of time required, specification of special skills, abilities or preparation.
  Equipment to be camouflaged - items required, length of time required, equipment condition required.
  Test range - specify size, terrain features, avenues of approach to the range, orientation of the range with respect to the approach direction, any construction or additions to the range such as distance markers or fixed observation sites.
  Logistic support - items and records required during the conduct of the test, transportation and communication required at the test facility, meteorological data during the test.

- Description of the test procedure
  - Statistical design showing sequence, location and combination of test conditions for each observation.
  - Data sheets to record subject's response to the observation.
  - Briefing and instruction sheets for each observer.

- Explanation of the proposed data analysis method
  - Analysis method should relate to the test design.
  - Give the mathematical model to be used to analyze the data.

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GLOSSARY OF TERMS

ACTIVE - Capable of acting or reacting especially in some specific manner, the opposite of passive.

BACKGROUND - The natural, physical, or material conditions that form the immediate setting against which something is viewed or sensed.

BLEND - To cause a target to appear as an element of its surroundings.

CAMOUFLAGE - The use of concealment (of truth) to minimize the probability of detection and/or identification of troops, materiel, equipment and installations.

CAMOUFLAGE CRITICAL - Designation of an item or system considered to have high camouflage sensitivity and high combat power.

CAMOUFLAGE GOAL - A statement of the perceptibility performance required of a camouflage treatment.

CAMOUFLAGE MEASURE - Actions undertaken to achieve a state or condition of camouflage.

CAMOUFLAGE METHOD - One of the four broad means of achieving camouflage: high, blend, disguise, and decoy.

CAMOUFLAGE SENSITIVITY - Designation of an item or system as needing camouflage to reduce perceptibility.

CAMOUFLAGE TECHNIQUE - A specific set of designs, constructions and actions to achieve a camouflage capability.

CC/CS - Camouflage Critical/Camouflage Sensitive Listing.

CD - Camouflage Detection (photographic) film. (Color Infrared type)

CLUTTER - Permanent echoes, cloud, or other atmospheric echo on radar scope, or contact has entered scope clutter.

COMPATIBILITY TEST - A determination of the capability of two or more items or components of equipment or material to exist or function in the same system or environment without mutual interference.

CONCEALMENT - The intentional denial to surveillance of an object, signature, signal or other evidence normally through blending, hiding and disguising.

CONTRAST - A comparison in respect of differences. The ratio of maximum and minimum luminances in a scene.

COUNTERMEASURE - That form of military science which by the employment of devices and/or techniques has as its objective the impairment of the operational effectiveness of enemy activity.

CUE - A characteristic or feature acting as an indication of the nature of the object or situation perceived.

DECEIVE - To cause to believe the false, to purposely cause incorrect conclusions based upon presentation of false evidence.

DECOY - An imitation in any sense of a real person or object displayed so as to deceive enemy surveillance and detection.

DETECTABILITY - An awareness of an object suspected of having military value. One of the four elements of survivability.

DETECTION - Discovery of an existence or presence.

DISGUISE - Alteration of identity cues of an item, signal, or system sufficient to cause misidentification.

EMISSIVITY - The ratio of radiation of an object within the infrared spectrum. A black body has an emissivity of 1.0; all other objects radiate less than 1.0.

EVALUATION - A subjective determination, accomplished jointly by the several major subordinate commands of the utility, that is, the military value, of a hardware item/system -- real or conceptual -- to the user.

EW - Electronic Warfare

FIELD TRIAL - The execution of a test or evaluation in the field as opposed to a laboratory or facility.

FIO - Foreign Intelligence Office/Officer

FLIR - Forward Looking Infrared

FOV - Field of View

GREY SCALE - A series of surfaces with known, graduated reflectances or emittances.

HIDING - Choice of position or materials to obstruct direct observation.

HITABILITY - The susceptibility of a target to being hit. One of the four elements of survivability.

IDENTIFICATION - Some level of comprehension in terms of categorizing an item or situation, e.g., military or nonmilitary, friend or foe, vehicle or tank, threat versus no threat, etc. Normally a rather high degree of confidence or assurance is implicit.

INTELLIGENCE - The product resulting from the collection, evaluation, analysis, integration, and interpretation of all information concerning one or more aspects of foreign countries or areas, which is immediately or potentially significant to the development of plans, policies, and operations.

IR - Infrared. That portion of the electromagnetic spectrum between 0.7 and 1000 microns in wavelength (between the visible and microwave regions). The military significant regions are the Near Infrared and the Thermal Infrared.

LINE OF SIGHT - The line between the target and the aiming reference.

LLLTV - Low Light Level Television

MICRON - 10^{-6} meter.

MICROWAVE - That portion of the electromagnetic spectrum between 10^{-3} and 10^{0} meters in wavelength.

MOE - Measure of Effectiveness

MOP - Measure of Performance

MTI - Moving Target Indicator Radar

NEAR IR - That portion of the electromagnetic spectrum between 0.7 and 2.5 microns in wavelength.

NVD - Night Vision Device

PASSIVE - Without either active participation or resistance of the individual affected, without interference to the act of observation (surveillance)

PERCEPTIBILITY - The characteristic, state, or quality of an item or system which causes it to be subject to detection, identification, and/or location by surveillance means.

PLATFORM - A base or support for a sensor.

PSYCHOLOGY - The science of mind or of mental phenomena and activities.

PSYCHOPHYSICS - A branch of science that deals with the problems (as the interrelations of the physical processes that constitute stimuli and the mental processes that result from their impingement on the living organism) common to physics and psychology.

RANGE GATING - A technique in which a sensor accepts only that portion of an emitted pulse of radiation that is returned in a specific time interval, thus effectively sensing only objects at a given range from the sensor.

RCS - Radar Cross Section

RECONNAISSANCE - A mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy.

REMOTE SENSING - Perceiving from a distance directly through the senses and indirectly through sensors which extend the innate sensing capabilities.

REMOTE SENSING THREAT - The detection (recognition) and hitability threat posed by enemy intelligence systems utilizing remote sensors, sensor platforms, data links, and enhancement means.

REPAIRABILITY - The characteristic of the ease and rapidity of replacing or repairing combat damaged equipment. One of the four elements of survivability.

REQUIREMENTS DOCUMENTS - Letter of Agreement (LOA), Letter Requirement (LR) Operational Capability Objective (OCO), or Required Operation Capability (ROC).

RESOLUTION - The act, process, or capability of rendering distinguishable the individual parts of an object, closely adjacent optical images or sources of light, nearly identical wavelengths of light, particles of nearly the same energy or mass, or events occurring at nearly the same time.

SAR - Synthetic Aperture Radar

SCENARIO - A series of episodes and conditions intended to simulate a military engagement.

SENSOR - A technical means to extend man's natural senses; an equipment which detects and indicates terrain configurations, the presence of military targets, and other natural man-made objects and activities by means of energy emitted or reflected by such targets or objects.

SIGNATURE - The characteristic pattern of the target displayed by detection and identification equipment.

SPECTROZONAL (MULTISPECTRAL) - A technique of recording a scene through several narrow band pass filters and selectively recombining that data to enhance the spectral detection of targets.

STANO - Surveillance, Target Acquisition, Night Observation Equipment and Systems.

SURVEILLANCE - The systematic observation of aerospace, surface, or subsurface areas, places, persons, or things by visual, aural, electronic, photographic, or other means.

SURVIVABILITY - That characteristic of personnel and materiel which enables them to withstand (or avoid) adverse military action or the effects of natural phenomena which would ordinarily and otherwise have resulted in the loss of capability to effectively continue the performance of the prescribed mission.

TARGET ACQUISITION - The detection, identification, and location of a target in sufficient detail to permit the effective employment of weapons.

TEST - A process by which data are accumulated to serve as a basis for assessing the degree that a system meets, exceeds, or fails to meet the technical or operational properties ascribed to the system.

THERMAL IR - That portion of the electromagnetic spectrum between 2.5 and .15 microns in wavelength. Also known as the Far Infrared Region.

THREAT - The capability of a potential enemy to limit or negate mission accomplishment, or to neutralize or reduce the effectiveness of a current or projected organization or materiel item.

THREAT ASSESSMENT - The process by which a specific threat is determined.

UGS - Unattended Ground Sensors

VISIBILITY - The horizontal distance at which a large dark object can just be seen against the horizon sky in daylight.

VULNERABILITY - The characteristics of a system which causes it to suffer a definite degradation (incapability to perform the designated mission) as a result of having been subjected to a certain level of effects in an unnatural (man-made) hostile environment.

WINDOW - A portion of the electromagnetic spectrum in which the atmospheric transmittance is relatively large.

INDEX

APPENDIX A

EXAMPLE PROBLEM

A-1 INTRODUCTION

One example is used throughout this appendix for continuity, thus making it possible to follow step-by-step the process of achieving camouflage for an item during its development. Many items now fielded, or in their final research and development or production phases, must necessarily follow the product improvement route of AR 70-15 to incorporate camouflage. The process for camouflaging these item/systems will follow the same logic and steps that are required for item/systems during development. Therefore, the example is adequate for this case too.

A-2 EXAMPLE OF ITEM SELECTION

A fictional weapon system was selected for an example through which approach and methodology could be illustrated, but without introducing a large array of close range remote sensing systems which would add needless complication. A system (rather than a single item) was chosen to bring out operational and ground signature characteristics which are not always associated with single items. Items which exist in large numbers, such as trucks and tanks, are generally found in groups and, as such, present ground patterns and standard operating procedure characteristics which must be taken into account in operational camouflage--but which are not directly concerned with individual item design and technical operations.

The fictional example system will be called "ZEBRA." The ZEBRA system has passed through its task force and conceptual life cycle phases and is now in its validation phase. It is a high cost system under development by a project manager. An approved LOA exists for this system. A ROC has been drafted for it, but has not been finalized. A hardware mock-up has been produced and a development plan outline was completed. This point in the life cycle has been chosen to illustrate the advantages to be gained by giving early consideration to the camouflage problem.

The ZEBRA system appears in the latest camouflage sensitive list. The Project Manager of ZEBRA is cognizant of this fact and has initiated action within his staff to comply with AMC Regulation 70-58.

The following brief description of the ZEBRA system is provided:

- PHYSICAL DESCRIPTION

  ZEBRA is a saturation rocket system capable of launching 32, 6-inch diameter rockets singly or in rapid salvo. The rockets have a maximum range of 10,000 meters. The launcher is transported on a flat bed truck containing one extra reload forward of the launcher assembly. Additional reloads of four sets are carried on a second carrier, a duplicate of the launcher transport vehicle. The launcher assembly is mounted on a swivel platform to provide rapid reload from the

second carrier and for vertical launching of missiles that permits firing from tree cover. The mechanism is powered by a central hydraulic pump.

Current design calls for the use of a draped tarp over both launcher and reload vehicles. The rockets may be fired from the cab in an emergency, but normal firing will be accomplished from a remote position by wire command. Aiming is accomplished by an on-board computer with position location using LORAN. The carrier consists of a standard truck bed with a diesel engine having vertical exhaust to the rear of the cab. The carrier is supported and leveled by hydraulic outriggers. Provisions for multiple guidance and warhead packages are included as attachments. Inertial guidance is normally used, but can be overriden by external coded radio or laser command beam rider or signals from an acoustic or thermal type homing device. Command link communication is by radio.

- OPERATIONAL DESCRIPTION

The system is primarily intended as a mobile point source interdiction to inhibit effective mass armor attack, and secondarily to serve as general artillery. In concept, it is intended that a density of 10 ZEBRA firing units will be deployed per type division. They will be attached for administration, protection, and support to a batallion size unit.

Support and re-supply are provided by standard 5-ton cargo trucks carrying several reload packages of 32 rockets each. A processing and checkout van is used to prepare the rockets as received from depot via a field distribution point. The communications gear and extra remote firing units are also carried in the van. The van is standard. A crew of eight is required and is transported in the firing, reload, and checkout and resupply vehicles. Other life support, plus security is to be provided by the unit to which ZEBRA is attached.

A-3 EXAMPLE OF THREAT ASSESSMENT

The Foreign Intelligence Office (FIO) was requested to augment the existing general threat contained in the development plan to enable a detailed estimate of the surveillance and target acquisition (S/TA) threat posed to the ZEBRA by the Warsaw Act Alliance during the period 1980-1990. To assist in this endeavor, the FIO was provided with the following information:

- Current LOA and draft ROC for ZEBRA
- General threat from the latest version of the ZEBRA development plan
- System description
- Operational concept
- Scenario and world areas of concern

The FIO was advised that their S/TA information would be of greater value if it could be summarized as follows:

1. By spectrum and spectral region as conventionally used (e.g., UV, Visual, Near-IR, etc.). The capabilities deemed most critical for each spectral region include:

   - Sensitivity bandwidths
   - Spatial resolution
   - Contrast resolution
   - Spectrozonal aspects

2. A series of graphs depicting the likelihood of effective observation occurring by direction and range within a vertical plane and using a probability of 0.95 and 0.5 when considering conditions of weather, terrain, frequency of observation (number of encounters with sensors) and other factors which may be deemed important, such as the likelihood of correct detections resulting from analysis of sensor acquired data. Three condition levels are desired: optimum, nominal, and poor.

   The term effective observation is used to indicate that the target is within effective range and view of sensors utilizing the particular spectral regions involved, and that the time of observation, platform speed, and other factors are satisfied. Enumeration of specific foreign surveillance devices and systems is unnecessary and undesirable.

3. An estimate of enemy capability to take offensive action against the ZEBRA system once it has been detected. This estimate should take into account both an ability to locate the system and its components, and the availability of suitable attack mechanisms and fire direction methods (TV, laser, visual, etc.).

The FIO response provided the data requested. A further analysis was conducted by the project manager's staff and led to the following findings:

1. The battlefield surveillance for targets of the ZEBRA type operating in the proposed geographic areas of central Europe and the middle East during the 1980-1990 time frame is expected to be only moderately improved from the current capability. Systems utilizing laser and holographic elements in remote sensing and analysis are expected to make the greatest progress and offer the greatest potential for any dramatic increase in effectiveness.

2. As currently proposed, the ZEBRA system does not appear to be susceptible to detection by nuclear, seismic or chemical monitoring and these have, therefore, been excluded from

further consideration. The remote sensing systems most likely to be a threat to ZEBRA include aerial photography, direct aerial observation, and infrared using both the 3-5 and 8-14 micron windows with FLIR the most critical systems in attack situations. SLAR is expected to be only moderately effective and airborne MTI will be a problem only during convoy movement. Direct view light intensification systems will augment night attack capability, especially from the air.

3. Estimates of effective observation occurring for each type of remote sensing considered a threat to ZEBRA are provided in a series of figures. Observation effectiveness refers to the combination of expected frequency that the target will be subject to a particular type of remote sensing, time of day, time available for observation, and platform speed. The estimates are presented as a likelihood of effective observation versus range and direction in relation to the ground plane. Three graphs are used for each remote sensing type to present the effects of optimum, nominal and poor conditions affecting observations in Europe and the Middle Eastern geographical areas.

4. Offensive action taken by an enemy to neutralize the ZEBRA system would most likely take place during the early stages of a general offensive because the ZEBRA is essentially defensive in nature and presents a threat primarily against vehicular targets within ranges of 8,000 meters. Reaction time from detection to attack can be very short for visual acquisition where rapid data links from the sensor to the fire control center are present. A vectored missile or aircraft attack using a form of homing munition are both within the capability expected in military forces of consequence by 1980.

5. An approximate (most likely) attack on the ZEBRA system will include (a) fighter aircraft (with FLIR) armed with rockets, bomblets, cannons, and napalm, (b) artillery of a conventional sort, and (c) stand-off guided missiles.

Information available indicates that the kill probability for targets of this nature once detected and under attack by any of the above on a single sortie basis is between .03 and 0.5. Moderate damage probability is between 0.4 and 0.8.

The following major detection and identification cues associated with the ZEBRA system in combat have been derived from analysis by intelligence and image interpretation personnel:

A. PREPARATION AND TRAINING MODE

(1) Surveillance

(a) An obvious and positive identity cue is the launcher rack mounted on a large flat bed truck.

(b) The association of the three large vehicles and a van.

(c) Signature steps in the checkout of missiles and other training activities.

(d) The size and nature of the system will restrict hiding to deep defiles and large buildings. The exposed nature of the equipment allows for significant solar heating during the day and long-time cooling at night. Exhaust engines and generators are unshielded and detectable.

(e) Signature details include the cable to the remote firing position; outriggers; support on launcher; ranging and communication antenna on van and the illogical context of having large flat bed cargo type trucks so close to FEBA.

(f) Vehicles are susceptible to SLAR detection but not readily identified. MTI detection on the convoy is likely.

(g) There are several electronic emissions during checkout and training which provide detection and identity cues.

(h) There is little concern for direct ground-to-ground observation for this system.

(i) Surveillance observation will most likely be from photography, DLIR, and visual sighting.

(2) Target Acquisition

(a) When in bivouac, the system presents an acceptable aerial target. When mixed in with support unit elements to which ZEBRA is attached, and using a normal amount of operational camouflage discipline, the probability of attack on ZEBRA is no greater than for any other military equipment in the same area.

(b) When in a simulated fire mode for training, the same cues are present as indicated in "C" below, "Fire Mission Siting and Installation Mode."

(c) Attack would likely be from fighter bomber aircraft using bombs, rockets, and cannon, or from long range artillery. In this mode, the system does not present a sufficient threat to invite attack by guided bombs and other high cost sophisticated weaponry.

B. CONVOY MODE

(1) Surveillance

(a) In this mode detection is assured when moving and will be a function of the number of times the system falls within the field of view and resolution of sensors used.

(b) Identity cues are the associated vehicles in number, kind and context of cargo-carrying vehicles near FEBA.

(c) No specific signature cues are present except electromagnetic emissions. These are characteristics of similar vehicles and, therefore, will be of little significance until associated with other evidence.

(2) Target Acquisition

(a) If a part of a larger contingent of vehicle traffic, there is little reason for ZEBRA to be singled out for attack. Attack is, therefore, reduced to chance unless surveillance has identified ZEBRA and is attempting to eliminate it under conditions where it is most exposed and vulnerable.

(b) Attack will be most likely from fighter bomber aircraft on a target of opportunity basis and by visual or FLIR acquisition and aiming using bombs, rockets and cannon. Stand-off helicopter attack by guided bombs is considered a low threat in this mode.

(c) Ambush attack by pre-registered long range artillery aimed at a specific road point for example, and controlled by forward observers or radio linked prepositioned sensors is possible, but not unique to this system. The system is large enough, however, to invite such fire if the enemy coverage is on a selective basis.

C. FIRE MISSION SITING AND INSTALLATION MODE

(1) Surveillance

(a) Firing positions may be expected to be utilized for several days prior to executing a fire mission. This mode poses an immediate threat to an enemy and one which will be high on his list of priority targets as a serious impediment to any attack by him.

(b) During siting, the likelihood of detection (convoy mode) will be high and nearly a one-to-one relationship to sensor coverage. Detection likelihood will decrease once the system is installed in an acceptable site and using a reasonable level of camouflage discipline during installation and while in place. If the position is in trees, defile or cluttered terrain, this detection likelihood will be further decreased.

(c) Tracks from a road net or across open terrain will increase the likelihood of detection and aid in identification.

(d) Once installed and quiet (non-operating), there is little to cause detection by surveillance other than through photography and downward looking FLIR.

(e) A major cue will come from the need to expose the launcher for firing. This exposure need be for only a very short time, however.

(2) Target Acquisition

(a) If the enemy is not planning an early engagement, attack will most likely be that of targets of opportunity.

(b) Assuming the enemy planned action and a serious effort to find all targets likely to impede his progress, surveillance will have located and identified this system as a serious potential threat and will direct an attack against it.

(c) Exposed or hidden from view, such an attack will attempt to destroy the launcher as the most vital point in the system. Attack may be directed against an area position only, or in this mode, sophisticated weapons may be considered warranted.

(d) Ground pattern and dispersion of equipment controls likelihood of hits in this instance.

D. FIRING MODE

(1) Surveillance

(a) In this mode, all the cues are present that existed in the Fire Mission Siting and Installation Mode. Siting and Installation plus the action of final positioning and direction of the launcher followed by flash, smoke,

dust, sound and electromagnetic impulses associated with firing and controlling the missiles together with communications from fire direction authority causes high probability of detection.

(b) Identity and signature cues include flash analysis, salvo fire, sound analysis and characteristic flight patterns; all detectable and capable of being used in a signature sense.

(c) The launcher and storage racks will produce a high radar cross section to SLAR, and except in a heavily cluttered background, will produce high detectability.

(2) Target Acquisition

(a) The above signatures can be used to locate the system within a reasonable CPE (circle of probable error) through triangulation, MTI radar, and IR backtracking systems.

(b) The same attack methods are likely as were used for previous ZEBRA system modes plus the added potential that IR seeker homing is now possible. Direct air attack is still most likely.

E. POST FIRING MODE

(1) Surveillance

(a) The additional detectable emissions available for a short period after firing are the thermal and blast effects on the surround terrain and launch vehicles.

(b) The reload operation after two salvos requires bringing two large vehicles side-by-side which increases the target cross-section to all sensors. Fortunately, this condition is short-lived, but tracks covering a reasonably large area will occur.

(c) This activity and ground pattern presents a sizeable identity cue.

(2) Target Acquisition

(a) The additional cues available in this mode, the need to move vehicles, etc., together with location data obtained by the enemy from firing, will cause the system to be more detectable and more likely to be attacked.

(b) Assuming the firing has caused damage to the enemy attack, the neutralization of the ZEBRA will be urgent, and may result in the expenditure of more resources to render ZEBRA ineffective. Attack against this mode will probably be an area coverage through conventional artillery or multiple sortie air attack.

A-4 EXAMPLE COUNTERMEASURE GOAL DETERMINATION

The threat analysis indicated that for targets of this sort, there is a high likelihood of enemy detection and effective counteraction which would seriously affect the survivability of the system. The example presumes that staff level communications have been maintained between all parties concerned.

As indicated in the text, two parallel actions are initiated at this point based upon the findings of the threat analysis. The first is that of conducting a parametric worth analysis (see Section 4) using several assumed levels of camouflage capability (and other countermeasures) ranging from the assumed baseline of the current system to a level of mission capability and survivability that produces a significant positive change in outcome of engagements played. The second and parallel action undertaken is that of determining, the current perceptibility (probability of detection, identification and hitability) of the ZEBRA system deployed as operationally intended and subjected to the fo ms of surveillance and target acquisition threats concluded from the threat analysis. It was determined that to save money, this perceptibility determination would be done using models at the Redstone Simulation Center and Radar Model Range at MERADCOM. The results of these studies was then to form a basis for confirmatory field tests in a northwestern and southwestern U.S. test site.

The model studies and field tests were accomplished and generally confirmed the detection and identity cues (perceptibility) indicated by the threat analysis. These studies provided quantifications of expected ranges and search times likely under a set of conditions and within the scenarios set forth against the threats of visual acquisition, photography, IR (DLIR and FLIR), SLAR and MTI radar where the threat analysis indicated they would be a threat.

In order to quantify, if possible, the Military Worth of ZEBRA camouflage, the combat model, which was used to investigate the firepower and maneuver options of the ZEBRA system (such as optimum rocket performance, number of rockets per reload, number of reloads available in the battery, number of vehicles in the battery, number of men in the battery, warhead lethality, employment doctrine, cross country mobility, reload time, resupply time ...), was used to investigate the effect of camouflage on the outcome of the battle played in the combat model. This model was modified to be able to account for ZEBRA camouflage and enemy attack aircraft. The attack aircraft was given the capability of a FLIR target acquisition system similar to that identified as the primary threat in the threat assessment.

Since ZEBRA was designed as a defense against massed armor attacks, the MOE chosen was the number of Red tank casualties during the battle. ZEBRA survival time after firing the first salvo was considered as a MOE, and survival time certainly would have a strong effect on the outcome of the battle, but it is not as good a measure of the outcome of the battle as is the number of tank casualties.

The Military Worth of ZEBRA camouflage will be judged in a simulation of an attack, by a red tank regiment (98 tanks, 20 BRDM's, 6 ZSU-23-4 gun systems, and 6 ZSU-57-2 gun systems), against a Blue defensive force of 20 tanks, 20 TOW launchers, 40 DRAGON launchers, and one ZEBRA system. The Blue force is in a prepared defensive position and each side is aware of the equipment and capabilities of the other. The combat model has two terrain sub-models, one representing central Europe and its prevalent weather condition, and the other representing a mid-East desert region and its prevalent weather.

Since the target acquisition threat played in this combat model was a FLIR mounted on an attack aircraft, the MOP used was that which would predict the behavior of the attack aircraft. The modification to the combat model, which included the camouflage and attack aircraft, described their interaction in terms of slant range. Slant range data was used as a decision rule; if the flight path of the aircraft is such that the ZEBRA is in the field of view of the aircraft, then the probability of target acquisition associated with the ZEBRA-to-aircraft range will decide whether or not the ZEBRA is acquired. If acquired, other program sub-models determine whether the aircraft can deliver damaging fire onto the ZEBRA.

The results of the Military Worth Analysis indicated that in all cases investigated, the Red force overran the Blue defensive position. When the uncamouflaged state of ZEBRA was played (acquisition range 4,000 meters), there were 20 Red tank casualties. When an acquisition range of 2,000 meters was played, 25 Red tank casualties occurred. And when an acquisition range of 1,000 meters was played, 30 Red tanks casualties occurred.

The outcome of the model and field tests of the current ZEBRA configuration has resulted in the following findings:

At the Eastern test site, the deployed system, in an open area, was detected within 15 minutes and positively identified within 18 minutes. Acquisition ranges, with pilots cued to the position, were between 3 miles and .5 mile with the mean at 2.12 miles. Deployed within wooded terrain, the initial detection and positive identification times increased to 30 minutes and 35 minutes (mean). Acquisition ranges decreased to .8 mile at low altitudes with no reduction in overhead viewing range.

Assessment of these combined results of the parametric worth analysis and the initial perceptibility study revealed that:

1. The system has no inherent means of physical self-protection other than operators using rifles and Redeye.

2. ZEBRA is most valuable to the defense at the time of enemy armor attack and the system is most susceptible to detection and attack (identification and location) at the time of active firing with the second most serious period occurring during the post firing reload mode.

3. The estimated time to detection varies from 15 minutes and 30 minutes, and the detection range will be on the order of 5000 + 1000m for attack and the most probable attack will be from low flying aircraft using FLIR or a terminal FLIR guided rocket. It is unlikely, although possible, that laser illumination would be utilized against this target.

   Results of the parametric study shows that if the system is to be militarily useful, it must have a target acquisition range of 1000m or less against the threat aircraft FLIR system.

The following camouflage goals were recommended for inclusion in the ZEBRA requirements document:

1. The target acquisition range of the ZEBRA be 1000m or less against the threat FLIR system.

2. The identity cues (indicated in Appendix A-2), which define the system as ZEBRA, be hidden, shielded, or eliminated.

A-5 EXAMPLE OF COUNTERMEASURE DEVELOPMENT

The ZEBRA was determined to be camouflage sensitive. Appendix A-3 discussed the request for a threat description and the analysis of that threat regarding the probable causes of detection and identification as well as an estimate of the likelihood of a resulting attack.

Appendix A-4 illustrates the further analysis for obtaining specific baseline perceptibility data relative to the threat capabilities indicated in Appendix A-3. A parametric worth analysis to establish significant camouflage level and the development of a statement of camouflage goals for inclusion in the ROC were also discussed in Appendix A-4. The recommended camouflage methods and techniques are presented as an example countermeasure development.

Based upon the results of previous countermeasure studies relating to ZEBRA, and the requirement to meet the goals indicated in the ROC, the following camouflage is proposed for inclusion and use by the ZEBRA system.

a. Equip both the launcher and reload vehicles with a rapid action accordion type bow and tarp disguise in lieu of the current tarps only. This disguise will collapse forward along special tracks on sides of the truck bed to a point forward of the auxiliary generator - pump. Incorporate wire mesh into the tarp to reduce the RCS resulting from the launcher and carrier. See Table 5-3 and Data Sheet 1203.

b. Replace the van with a standard combat cargo truck of appropriate size carrying a prefabricated operations shelter beneath the standard bow and tarp. See Table 5-7.

c. Assign standard camouflage screen modules as required for each truck in the system to utilize the existing QCD for exposing the launcher for firing on short notice. These screens are to be employed primarily in concealing firing positions prior to initial firing and to prolong detection-identification after the missiles are launched. Local materials and camouflage discipline are prescribed to increase concealment for longer times spent in one position. See Data Sheet 2000.

d. Insulate and shield the exhausts, engine compartments, and launcher erector to meet reduced FLIR detection ranges. See Data Sheet 1202

e. House the auxiliary generator and compressor in a thermally shielded compartment using combined radiative and air cooling with an overhang awning plus air cooled louvers to deflect cooling air away from nearby foliage. See Data Sheet 1202.

f. Cover the launcher and rocket rack with shaped metal mesh or screen to deny SLAR the large RCS which results from these racks. See Data Sheet 1203.

g. All vehicles will be pattern painted and equipped with external windshield, headlight and side window shields incorporated. See Table 5-6 and Data Sheet 3006.

h. Communications antennae will be collapsible into a recess during non-use.

i. Develop and incorporate a metalized fabric flash shield for deployment around the launcher in its vertical launch position. See Data Sheet 1202.

j. Provide decoy flash and sound generators for synchronized use at time of launch. Provide exothermic heat generators and corner reflectors to confuse FLIR and RADAR search and attack. These items are to become a part of the operational SOP and a part of the ZEBRA TO&E. See Data Sheet 1400 and 1402.

k. Incorporate a fluid tank, hoses and appropriate spray heads to spray the launcher and immediate area with a cooling fluid.

1. Develop (or adopt) a rocket dispersed thermal and radar screen in cooperation with appropriate EW organizations to deny accurate backtracking. This screen, when emplaced above the ground clutter height and combined with the vertical launch feature and joined with the decoys in j above, are expected to sufficiently delay location of the ZEBRA for a time exceeding that indicated as necessary in the worth analysis. See Data Sheet 2001.